Pathways to Carbon Neutrality in California: Clean Energy Solutions that Work for Everyone

A SUMMARY OF INTERVIEW AND WORKSHOP FINDINGS

September 2021

Stanford
Center for Carbon Storage
Carbon Removal Initiative

About

About the Stanford Center for Carbon Storage

Carbon Capture, Utilization, and Storage is a key technology for achieving net-zero greenhouse gas emissions. The Stanford Center for Carbon Storage (SCCS) uses a multidisciplinary approach to address critical questions related to flow physics, monitoring, geochemistry, geomechanics and simulation of the transport and fate of CO2 stored in partially- to fully-depleted oil & gas fields and saline reservoirs. SCCS is an affiliates program associated with the Stanford University School of Earth, Energy and Environmental Sciences.

About the Stanford Carbon Removal Initiative

The Stanford Carbon Removal Initiative (SCRI) seeks to create science-based opportunities and solutions for gigaton-scale negative emissions and atmospheric carbon removal. The initiative helps to enable removal of atmospheric greenhouse gasses at scale by generating and integrating knowledge, creating scalable solutions, informing policies for technology deployment and governance, and demonstrating approaches and solutions with industry collaborators. All of this is done with a focus on social acceptance and equity, as well as environmental, economic, and social costs. SCRI is an affiliates program associated with the Precourt Institute for Energy and the Woods Institute for the Environment.

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California Manufacturers & Technology Association

California State Building and Construction Trades Council

International Brotherhood of Boilermakers

Western States Petroleum Association

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List of Acronyms

AB	Assembly Bill
AQMD	Air Quality Management District
BECCS	Bioenergy with carbon capture and storage
BTM	Behind-the-meter
CAES	Compressed air energy storage
CAISO	California Independent System Operator
CARB	California Air Resources Board
CalEPA	California Environmental Protection Agency
CCA	Community choice aggregator
CCS	Carbon capture and storage
CEC	California Energy Commission
CNG	Compressed natural gas
CO_2	Carbon dioxide
CPUC	California Public Utilities Commission
DOE	United States Department of Energy
DR	Demand Response
DSO	Distribution system operator
EIM	Energy Imbalance Market
EJ	Environmental justice
EO	Executive Order
EV	Electric vehicle
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse gas
GW	Gigawatts
ICE	Internal combustion engine
IOU	Investor-owned utility
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent power producer
IRP	Integrated Resource Planning process
ISO	Independent system operator
MtCO2e	Million tons of CO_2 equivalent
PM	Particulate matter
POU	Public utility
R&D	Research and development
REC	Renewable energy credit
SB	Senate Bill
SMR	Small modular reactor
T&D	Transmission and distribution
TCO	Total cost of ownership
TOU	Time of use pricing

This report summarizes insights from a series of interviews conducted in the spring of 2021 as well as a workshop conducted in June 2021. This report does not necessarily represent the views of Stanford University or the project sponsors.

Key Findings

California Policies

- It is important to have many groups involved in the carbon neutrality conversations in order to achieve the most effective long-term results.
- State needs to do a better job of coordinating policy development with implementation of these policies.
- Properly addressing infrastructure needs and requirements is a critical part of overall implementation.
- Greater coordination with private sector will ensure that new policies do not significantly impact economy and jobs.
- The state of California could have more impact by supporting the development of new technologies originating from in state national laboratories, industries, and universities.

Regulation

- There are concerns that various state agencies do not coordinate their work to the necessary degree, leading to confusion for organizations required to meet regulatory mandates.
- Coordination between local governments and state agencies can be improved.
- Private sector has concerns over changing regulatory mandates and the costs of achieving these mandates, leading to possible movement of industry out of state.

Electricity

- Push towards electrifying much of state's economy ("all the eggs are in one basket") leads to uncertainty as to how to achieve carbon neutrality while expanding the grid and increasing renewable generation to close to 100%.
- State agencies and legislature need to allow for flexible approaches for reaching carbon neutrality that are economically reasonable. This may require retention of nuclear and natural gas generation.
- Public-private partnerships must work together to achieve state goals, but one state organization must be acknowledged as the leader.
- Planning and implementation must be cognizant of risks to the grid in terms of reliability, resiliency, potential for equipment failure, and cyber-attacks.
- New modeling and analytical tools need to be developed that better characterize the changing grid operations and future risks.
- To maintain grid reliability, it may be necessary to maintain natural gas-fired generation. Carbon capture and storage (CCS) technology would be employed to remove carbon dioxide.
- Due to significant ramping needs in the late afternoon, fast starting gas turbines would still be required.

- Upgrading and expanding transmission and distribution (T&D) systems will require coordination between different state and local regulators and the political will to address expanded state T&D needs.
- There needs to be a better understanding of how behind-the-meter generation and storage fit into the operation of the overall grid.
- Significantly expanded electricity needs, such as for electric vehicles (EVs), will impact grid operations.
- Cost of infrastructure expansion must consider impacts on lower income families.
- Additional technology development is necessary for CCS, bioenergy technologies, hydrogen technology, long term storage systems, and information and communications systems.

Transportation

- Utilities and state agencies need to work together to properly plan for the widespread installation of EV charging stations.
- There are divergent opinions on the maturity of EV technologies for larger vehicles. Proponents believe it is here now for trucking and transit, while others believe the costs are currently too high.
- Trucking industry is concerned that they will lose market share to out-of-state competitors who have cheaper vehicles.
- Hydrogen is currently too costly for cars and the trucking industry.

Buildings and Energy Efficiency

- SB 350 and Title 24 standards require future homes to be zero net carbon structures, with the building industry being prepared to address that.
- For new structures, the embodied carbon dioxide emissions should be considered. New construction materials can reduce overall embodied emissions.
- Most significant building issue is the need to retrofit existing structures, since they cause considerable carbon dioxide emissions. There were 110,000 new building permits in 2019, but there are 14 million existing homes.
- State should consider incentives and requirements that will promote improved energy efficiency and carbon dioxide reduction. This could include support to landlords and requirements for retrofitting upon a sale of a home.
- Codes and standards must be updated in order to properly address state carbon neutrality goals
- Additional education may be required for electricians and architects for working with new materials and appliances.
- More building in urban centers could reduce carbon dioxide emissions due to reduction in commuting.
- Utilization of load shifting technologies – demand response systems – can reduce overall emissions by using more renewable energy during the day and less fossil-fired generation during evening hours.
- Consideration should be given for assisting low income families for reducing carbon dioxide emissions for their homes and vehicles.

Industry

- State can do a better job by engaging industry to take advantage of its technology and operational innovation.
- Industry is concerned that they can lose competitive advantage to out-of-state competitors due to needing to deal with increased operational costs.
- Small businesses are seen as not having sufficient capabilities for addressing new carbon neutrality regulatory requirements.
- Many industries use natural gas due to high temperature processes, with electricity not being an option in these circumstances.
- The cement industry is developing new lower-carbon intensive cements that can be used on roads and in building construction.
- Many industries believe that CCS is a solution to process heating needs.
- Life-cycle analyses would be useful in evaluating embedded energy and carbon dioxide in materials.

Forestry and Agriculture

- Use of forest management wood waste can reduce carbon dioxide emissions by 98% compared to forest fires.
- New forms of wood materials can be used in place of steel and cement, cutting overall embedded carbon emissions.
- Biomass combustors can use CCS, leading to potentially negative emissions.
- Livestock produce 2 to 4% of state-wide greenhouse gas emissions, primarily methane.
- Goal of livestock industry is to reach 50% of state mandated goal for reduced emissions by 2022. The goal is 9 Mt CO_2e in 2030.
- New methods are being developed for animal feed to reduce emissions, as well as development of more efficient anaerobic digestors.

Socioeconomic Aspects of Meeting Carbon Neutrality Goals

- State needs to have marketing and educational campaigns that are directed towards changing consumer behavior.
- State should be prepared to help displaced workers from industries being phased out.
- Job retraining needs to address developing well-paying and secure jobs in new sectors.
- For retraining, there should be financial support for workers who have lost their jobs and are back in classes.
- Public-private partnerships can be important in retraining workers.
- Although state supports environmental justice (EJ) needs, implementation of new approaches may not meet the needs of EJ communities.
- In addition to carbon neutrality goals, reduction in air pollution is needed for low income communities.
- There will need to be subsidy programs for low income families in reducing their residential carbon dioxide emissions and in providing financial support for the purchase of EVs.
- There is a need to involve EJ community in earlier discussions concerning state policies and mandates.

Report Briefs

The interview and workshop summary report contains a lengthy rich summary and discussion of the project findings. The following 6 briefs are intended to provide additional insights into themes that emerged during the interview and workshop process. The following briefs are included:

#1: The Supreme Importance of Reliable and Resilient Electricity
#2: The Need to Address Existing Buildings
#3: Net Zero is Easier with Carbon Removal
#4: Should I Stay or Should I Go? The Challenge of "Leakage"
#5: Engagement Should Be More Inclusive
#6: Time is of the Essence

BRIEF # 1

PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

The Supreme Importance of Reliable and Resilient Electricity

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses findings that emerged through a series of interviews held in the spring of 2021, and a virtual workshop held in June 2021, in which over 115 stakeholder participants discussed Pathways to Carbon Neutrality in California.

It's not easy to keep the lights on.

Participants described California's strategy for achieving carbon neutrality by 2045 as "electrify everything and decarbonize the grid". This entails a dramatic increase in electricity production and consumption (two to three times current demand), with widespread implications.

CALIFORNIA'S HISTORY OF BLACKOUTS is familiar to many residents. One reason that Governor Gray Davis was recalled was the 2000/2001 California electricity crisis that included rolling blackouts. Electricity reliability continues to be critically important to California and Californians, and this importance is bound to increase as the state "electrifies everything" on the way to carbon neutrality.

This brief explores the importance and challenges around hardening the grid; that is, keeping the grid up and running (reliability), and preparing strategically to respond to the inevitable blackouts (resiliency).

AS EASY AS FLIPPING A SWITCH – THE CHALLENGE OF RELIABILITY

The electrical grid is a truly amazing human invention. It allows people to flip a switch and power their homes and businesses, without a thought as to how it happens. However, much effort, planning, and infrastructure is required to ensure that electricity supply matches electricity demand every second of every day, and that electricity is available wherever and whenever it is needed. This is the challenge of *reliability*.

The new system primarily powered by intermittent energy resources creates new questions for how the grid can deliver electricity on demand, with high reliability.

POWER WHERE YOU NEED IT – INCREASED TRANSMISSION AND DISTRIBUTION

The new system will require new and expanded infrastructure for transmission and distribution systems moving massive amounts of power over great distances. ***How can California manage a large buildout of transmission and distribution?***

POWER WHEN YOU NEED IT – SYSTEM RESERVES

Participants pointed out that reliability requires sufficient reserves of on-demand ("firm dispatchable") power to handle sudden spikes in demand. The current system does this with natural gas power plants, geothermal, hydropower, and the Diablo Canyon nuclear-powered plant in California as well as fossil-fired resources in other states. As California moves towards a carbon-neutral future, the fossil-fuel resources that serve this role seem destined to be retired and replaced by intermittent, non-dispatchable renewables whose output is indifferent to demand. ***How will firm dispatchable reserve capacity be provided in the new system?***

POWER WHILE TRANSFORMING THE SYSTEM

The properties of electricity from renewables (mostly in remote locations) and storage are very different from current, mostly fossil-fuel based fuel generation. A participant described this as "changing the tires while the car is speeding down the freeway". ***How can California manage the changes from the current system to the new system?***

RAPID-RESPONSE RESOURCES TO BACKFILL FOR INTERMITTENT RENEWABLES

Participants pointed out the significant and growing issue that occurs every day as the sun goes down, when solar generation drops off just as evening demand picks up. Keeping the lights on requires the availability of utility-scale electricity sources that can rapidly be brought to bear to provide large quantities of power. Similarly, should the wind suddenly stop blowing the system must be ready to "turn on a dime" and quickly provide other sources of electricity. ***How will California provide flexible, rapid-response electricity supply at large scale?***

THE EMERGING NEED FOR STORAGE

Participants broadly perceived that, should generation become primarily or exclusively renewables, storage will be the key to resource adequacy because sometimes "the sun doesn't shine and the wind doesn't blow." Participants believed that utility-scale storage will be of particular importance. In addition, there might be some system benefits to distributed storage (e.g., electric vehicles and behind-the-meter battery storage that is coupled to rooftop solar), although grid operators currently do not have the technology that can access these possible storage resources. ***How will California system operators analyze, site, build, and manage large-scale storage on the grid and on distributed systems?***

In addition to the short-term storage which provides a buffer for the vagaries of sun and wind, participants indicated that long-term storage must play an important role in order to handle extended periods of either high demand (e.g., a lengthy heatwave) and/or low renewables supply (e.g., excessive clouds, or low winds in winter time). ***Are California and the country adequately investing in the development of long-term storage technologies?***

VEHICLE BATTERIES FOR FIRM POWER

Some participants discussed the possibility of using vehicle batteries as a source of firm dispatchable electricity supply during times of shortage. However, it is uncertain whether EV manufacturers will warranty their batteries for frequent cycling for supporting grid electricity shortfalls. ***What role should vehicle batteries play in reliability planning and assessment?***

In addition, there is a risk that if a blackout were to occur after the vehicle battery has been partly or fully discharged, the vehicle will be less effective for transportation. This might discourage users from allowing their vehicle batteries to be used to support the grid, which in turn might make the grid less reliable. ***How might electricity reliability concerns affect enrollment in programs to use car batteries as a grid resource?***

PUBLIC SAFETY POWER SHUTOFFS DUE TO INCREASED WILDFIRE THREAT AND INTENSITY

Due to climate change, California has seen a significant increase in the magnitude and intensity of wildfires. Once rare wildland megafires now occur with increasing frequency. Wildland fire risk conditions routinely lead to public safety power shutoffs (PSPS). These events, which are predictably unpredictable, can last for many days. Some regions of the state are experiencing relatively frequent PSPSs. Some participants suggested that self-sustaining microgrids in certain areas might be wise. ***How can the state ensure reliable electricity supply during wildfire season?***

RELIABLE PROVISION OF GRID SERVICES

Many participants recognized that "reliability" includes not only sufficient energy, but also the provision of other grid services that stabilize and condition power. ***How can grid services be maintained as the grid moves from a central-station firm power model to one that must embrace distributed generation and intermittent resources?***

NEW COMPLEXITY REQUIRES NEW THINKING

The new system brings new uncertainties and coordination needs. The need for new and improved models, analytical methods, policies, and regulations that need to be implemented will be considerable. ***How will California understand, model, analyze, and run the new system?***

DISRUPTION HAPPENS – THE CHALLENGE OF RESILIENCY

The previous section discussed reliability, which is the challenge of matching electricity supply to demand, everywhere, all the time. Reliability requires careful attention even when everything is going well. However, sometimes things don't go well and the system experiences a disruptive event (e.g., falling tree, mechanical failure, computer glitch, etc.). We need to take steps so that when a disruptive event does occur, we can avoid a blackout or at least minimize the extent of its harm. This challenge is called *resiliency*.

Resiliency has many aspects, and there are many ways to think about it. In this brief, we use a resiliency framework developed by the Pacific Northwest National Laboratory which proposes that resiliency comprises actions taken to *prepare* for disruption; to *operate* at some level during disruption; and to *restore* electricity promptly after disruption.

PREPARE – KEEP BLACKOUTS LOCAL

Participants pointed out that in the past, there have been many instances where a local blackout due to local problems spread quickly to other areas. Participants indicate that it is possible to establish a robust transmission system to stop blackout "contagion." However, a robust grid must be purposefully built. Participants also observed that micro-grids can be helpful in this regard. ***How will California ensure a robust grid that can localize blackouts?***

PREPARE - ELECTRIC VEHICLES DURING BLACKOUTS

Decarbonization requires that vehicular transportation be electrified or use "green" hydrogen in fuel cell vehicles. During a blackout, electrical vehicles won't be able to charge.
How can electric vehicles be re-energized in the event of electricity outages?

PREPARE - DEFEND AGAINST CYBER THREATS

Participants identified cyber security as an important risk to system reliability. They pointed out that decarbonization is "tech heavy" and more technology means more risk. They identified distributed systems as having many vulnerabilities (access points), including solar inverters, smart buildings, and smart grids. Participants also identified communications and control systems as points of cyber vulnerability. ***How will California provide a systematic and robust defense against cyber threats?***

OPERATE – CRITICAL INFRASTRUCTURE

California will need to ensure that critical infrastructure, including hospitals, emergency first responders, and public safety radio nets will be able to operate when the grid has gone offline. Participants suggested several solutions to this challenge, including microgrids for critical infrastructure locations, new forms of long-term storage, and/or the use of fossil-fired generators. ***In a carbon neutral future, what will be the best strategies for ensuring that critical infrastructure is maintained and responsive during a blackout?***

OPERATE – SUSTAINABILITY OF DISTRIBUTED BACKUP POWER FOR LONG OUTAGES

Most blackouts are of short duration, a few hours. As we have seen recently in California, some blackouts can last for days. Currently, easily-refueled fossil-fuel generators are the usual backup, but these will presumably become less prevalent during the transition to net zero carbon. ***How will distributed backup power be provided during blackouts?***

Backups could be in the form of battery storage, or hydrogen fuel cells. If backups are based on batteries, reenergizing during a lengthy blackout will pose a challenge. ***How will battery and fuel cell backups be re-energized during blackouts?***

It is too soon to say how important hydrogen and hydrogen fuel cells will be to the energy transition. It is likewise too soon to say how hydrogen will be provisioned (manufactured and transported). To the extent that hydrogen provision is dependent on electricity (e.g., electrolysis) hydrogen supplies could dwindle rapidly during a blackout. ***How will hydrogen backups be provisioned with hydrogen during blackouts?***

RESTORE - GRID INFRASTRUCTURE

The electricity grid is one of the most complex machines ever devised, and the California energy transition increases its complexity. The new grid with its attendant complexities and communications channels may be challenging to get back up and running after a blackout, especially if there is substantial damage to distributed generation (e.g., residential solar inverters), storage, or communication networks. ***Are there adequate technologies, systems, and regulations to enable rapid start-up from any grid outage?***

RESTORE – WEATHER-CAUSED BLACKOUTS

In a changing climate, weather impacts are likely to include severe wildfires, torrential rains and flooding, high winds, and extreme heat. These present challenges to reliability, but they also present challenges to recovery. It is possible that careful pre-planning and investment could make recovery more rapid than now. ***Can California develop mechanisms so the new system can recover quickly from weather-caused blackouts?***

RESTORE – CYBER ATTACKS

Cyber attacks can take many forms. Recovery can be a challenge. Some cyber-attacks include extortion demands and a rapid decision on whether to meet those demands can affect the time to recovery. ***Can California develop mechanisms to recover quickly from likely cyber attacks?***

All Our Eggs Are in One Basket

This brief highlights some of the risks and challenges of transitioning from the current energy system to an all-electric system that is based on renewables. California's strategy of "electrifying everything" entails at least a doubling of electricity usage, with pretty much everything (transportation, building heating, industry, commerce) running on electricity. This represents a massive bet on electrical reliability and resiliency.

California's strategy of "decarbonizing the grid" entails retirement of significant amounts of firm, dispatchable fossil fuel generation and its replacement by intermittent, non-dispatchable renewables, buffered by storage. This is a massive bet on the state's ability to site, design, build, operate, and pay for a type of system never before undertaken at this scale.

The goal of carbon neutrality may be a pathway for reducing a diversified and broad portfolio of energy resources to a less-diversified and narrower portfolio of electricity resources powered by renewables and storage. ***Is an integrated system that has multiple energy sources more resilient than a system that is purely electrical, or purely renewables?***

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BRIEF # 2

PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

The Need to Address Existing Buildings

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses findings that emerged through a series of interviews held in the spring of 2021, and a virtual workshop held in June 2021, in which over 115 stakeholder participants discussed Pathways to Carbon Neutrality in California.

California can't build its way out of this – Existing buildings must be retrofitted.

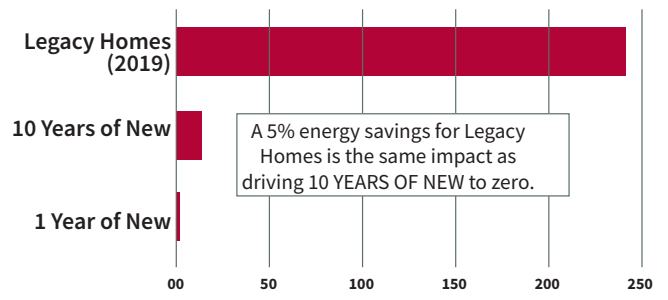
Buildings represent 13.7% of California GHG emissions. California is setting high standards for new buildings with codes and regulations specifying energy efficiency, requiring photovoltaic systems, and starting to discourage or forbid fossil fuel appliances for space heating, hot water, and cooking. The state is on the way to eliminating carbon emissions from new buildings. However, new buildings are less of a problem than existing buildings.

OVER THE LAST FIVE YEARS, California has added about 85,000 units per year of housing.[1] Ten years of construction at this rate will yield around 850,000 new homes. In contrast, California has around 14 million existing homes, which is 15 times greater than ten years of new home growth. Buildings are long-lived, so almost all existing homes will still be in use in 2045.

LEGACY HOMES MUST BE RETROFITTED

Using simple averages for energy consumption, Figure 1 shows residential energy use for legacy homes and for new construction (10 years growth, and also 1 year). Notice that energy use for 10 years of new homes is a small fraction of energy use for existing homes. To put these numbers in perspective, a mere 5% reduction in energy use from legacy homes would be the same as driving energy use from new homes to zero.

FIGURE 1: ANNUAL RESIDENTIAL ENERGY USE



There are two ways to reduce the carbon impact of existing buildings. One is to reduce the need for heating and cooling by improving the thermal envelope. The other is to convert fossil-fuel appliances to electric (furnaces and hot water heaters to heat pumps; gas stoves to induction). This brief discusses challenges to retrofitting existing buildings. (Although this document focuses on residential buildings, the issues are similar for commercial buildings.)

1 US Census data: https://www.census.gov/programs-surveys/popest/technical-documentation/research/evaluation-estimates/2020-evaluation-estimates/2010s-totals-housing-units.html

Challenges for Retrofitting Millions of Existing Buildings

RETROFITTING ELECTRIC APPLIANCES IS HARD

The conversion to electric appliances is not as simple swapping out old with new. There is a one-time need to upgrade wiring and cap legacy gas lines. Wiring upgrades can trigger mandates to upgrade portions of the building's electrical system to modern codes, and perhaps necessitate an increase in electrical service capacity. Compared to a like-for-like swap, these improvements entail more sophisticated planning, more complex permits, a more elaborate inspection, and more sophisticated installers, leading to increased cost and time.

PROACTIVE REPLACEMENT IS BENEFICIAL

When an existing furnace, hot water heater, or stove fails, replacement is a matter of some urgency, and a prompt, like-for-like swap is routine. Residents without heat or hot water may be reluctant to accept the delays required by converting gas to electric. Therefore, participants noted that conversion should be done proactively, not at time of failure. ***How can millions of building owners be induced to replace fossil-fuel appliances prior to failure?***

AVAILABILITY OF TRAINED LABOR

Participants noted that a substantial increase in the number of electricians, already in short supply, will be critically important for the residential conversion to electricity. Conversion will also sometimes require skills in plumbing and construction. ***Is there opportunity to create streamlined certification for technicians who install heat pumps?***

PREPARATION OF BUILDING DEPARTMENT OFFICIALS

Participants identified an issue that local building departments may not always be familiar with relatively new technology such as heat pumps. For reasons of public safety, they can only approve installations that they understand. ***Is there opportunity to educate local officials on installation of heat pumps and induction stoves?***

SUPPLY OF ELECTRIC APPLIANCES

Participants indicated that it is difficult to source electric heat pumps because currently there is only a small market with few manufacturers, limited models, and large commercial heat pumps are simply not being manufactured. ***Can heat pump supply and R&D be incentivized?***

THE NEED FOR SCALE

Retrofits need to be done to millions of buildings in only a couple of decades. Existing programs are on a house-by-house basis. ***Can programs be designed to achieve large economies of scale and scope?***

DESIGN OF SUBSIDIES AND INCENTIVES

Participants indicated that subsidy and incentive programs are fragmented across many agencies and can be hard to navigate. ***Can programs be designed to require minimal initiative by residents/owners?***

SOCIAL JUSTICE

Participants point out that low-income residents often lack the wherewithal to undertake retrofits. ***How can low-income residences be retrofitted?***

SPLIT INCENTIVES

Participants identified that for energy efficiency improvements, the property owner pays the cost yet the tenant reaps the benefits of lower utility bills. ***How can this split-incentive problem be addressed?***

UTILITY COST

The cost for space heating and hot water is higher with electricity than with fossil fuels. ***How can the increased utility costs of electrification be addressed, especially for low-income people?***

FINANCING ENERGY EFFICIENCY

Participants point out that some energy efficiency projects for older homes, especially those in low-income areas, have a short payback period, yet the work is often not done. ***Can programs rapidly implement financially-attractive energy-efficiency improvements at scale?***

CAPITAL EXPENSE

Electric conversion can be expensive, even for the "willing and able". ***Can attractive, scalable financing options be devised, especially for people less knowledgeable about the complexities?***

DISTRIBUTION SYSTEM

In some areas, the electricity distribution system might need upgrades to handle increased demand resulting from the conversion from fossil fuel to electric appliances. ***Can distribution upgrades be coordinated with residential electrical conversion?***

Ambitious Undertaking

Participants noted that to convert millions of buildings from fossil fuels to electric heat, hot water, and cooking in 24 years is a very ambitious, perhaps unprecedented undertaking. One participant proposed a "moonshot" for the massive amount of retrofitting that is required. ***Are vendors, workforce, financing mechanisms, and public opinion prepared for the actions required? Is there opportunity to rethink the philosophy of programs, subsidies, regulation, etc. to undertake successfully the ambitious scale of work in the time available?***

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BRIEF # 3

PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

Net Zero is Easier with Carbon Disposal (Utilization & Storage)

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses findings that emerged through a series of interviews held in the spring of 2021, and a virtual workshop held in June 2021, in which over 115 stakeholder participants discussed Pathways to Carbon Neutrality in California.

Get Rid of Carbon, Not Just Creation of Carbon.

The goal of net zero by 2045 requires that California find a pathway such that any CO_2 created in the state be responsibly disposed of. Participants agreed that California will have to massively reduce the amount of CO_2 it creates. One pathway to net zero is "perfect zero" — to produce no CO_2 whatsoever by rigorously eliminating every CO_2-creating activity without exception. A more flexible pathway to net zero is to balance residual CO_2 creation with equal volumes of CO_2 disposal[1], where this balancing is the "net" in "net zero".

THE PATHWAY OF PERFECT elimination of CO_2 creation has "face value" attractiveness. However, some important economic activities currently have no practical alternative to creating CO_2. Other activities have "edge cases" where the cost or consequences of complete elimination could be unacceptable. Some things people want to do (such as deploy hydrogen at scale) are easier if CO_2 can be created and immediately disposed of. Finally, 2045 is less than two and a half decades away. For these reasons, a diversified portfolio of options, including carbon disposal, can greatly ease the path to net zero. In this brief, we discuss the advantages of pathways that include carbon disposal.

THERE IS NO PRACTICAL ALTERNATIVE AT PRESENT TO FOSSIL FUELS FOR SOME INDUSTRIAL PROCESS HEAT

Several participants identified three industries that require fossil fuels because the necessary industrial process temperatures are higher than can be provided cost-effectively using electricity; these are the manufacture of cement, glass, and steel. These commodities are important; as one participant put it "we will build a new planet in the next 40 years" – i.e., the next 40 years of worldwide construction will equal total prior construction. Another participant said, "we need a Plan B" (disposal) because these industries can't avoid CO_2 emissions.

Research into biofuels, hydrogen, or materials science might yield low- or no-carbon heat sources suitable for these industries at acceptable cost, but for now there is no alternative to fossil fuels and consequent CO_2 creation.

CEMENT MANUFACTURE CREATES CO_2 AS BYPRODUCT

Cement is an essential component of concrete, and concrete is ubiquitous in construction and repair of buildings, roads, and other infrastructure. Participants pointed out that the chemistry of converting limestone into cement produces CO_2 as an unavoidable byproduct, so even if the process heat challenge discussed above could be overcome, the CO_2 byproduct remains. Participants indicated that cement is "10% of concrete but 90% of concrete's CO_2", with roughly 60% of the emissions being byproduct and the rest coming from fuel combustion.

ACTIVITIES WHERE SOME USE CASES MAY NOT REASONABLY BE DECARBONIZED

Many participants indicated that achieving almost-complete decarbonization is relatively straightforward but that driving to 100% is very difficult[2]. One participant spoke of "the challenge of the last 10%", another that "the last 3% of emissions is incredibly expensive". These are expressions of "diminishing returns" which is well-known in economics.

Participants indicated that aviation and shipping pose a challenge. There may be unique decarbonization challenges for people who live off-the-grid or other residents of rural communities which as one participant put it "are disadvantaged".

DESIRABLE ACTIVITIES CREATE CO_2

Participants pointed out the potential net-zero benefits of using hydrogen as an energy source, and that "blue hydrogen" from natural gas, with CO_2 as an unavoidable byproduct, can be an attractive means of obtaining hydrogen provided the CO_2 byproduct is disposed of.

Some participants indicated that using biomass as fuel is inherently net zero, and that as a bonus much of the resultant CO_2 can be disposed of using a technology called BECCS.

ELECTRICAL RELIABILITY MAY REQUIRE SOME GAS GENERATION

Participants broadly agreed that on average sufficient carbon-free electricity will be available. However, some days are not average (e.g., hot fall afternoons with high air conditioning demand), and participants pointed out that there exists a need for "firm dispatchable" electricity. This need could not be met by renewables unless very large amounts of storage were available. Several participants indicated that it will be necessary to use natural gas generation to avoid blackouts, with the need being especially acute when there are multiple extreme-heat days in a row. Several participants saw pathways where, for reliability reasons, California's gas generation capacity (but not emissions) actually increase by 2050.

CO_2 DISPOSAL AT SCALE IS ADVANTAGEOUS

Participants perceived that the most attractive pathways for net zero by 2045 include residual CO_2 creation, and for these pathways, CO_2 disposal is necessary for net zero. CO_2 disposal is advantageous in avoiding the costs, consequences, and risks of pathways that rely on completely eliminating all CO_2 creation.

Fortunately, there are prospects for carbon capture at the source of creation for cement and gas electricity generation (and perhaps glass and steel), which coupled with disposal could enable these industries to operate at net zero. We note that carbon disposal technologies must be effective, permanent, available, and economic, and must be used at scale.

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1 We use "disposal" to mean locking CO_2 away for the long term through utilization (beneficial use such as adding it to concrete), or storage (sequestering it in geologic formations, in plants and soil, or other means).

2 Although not mentioned by participants, it may be difficult to eliminate emissions from sources including legacy vehicles, fossil-fuel hobbyists (e.g., classic cars and farm machinery), backup generators, gas cooktops, propane use in isolated regions, and low income people who can't afford the capital cost to transition away from gas or fuel oil.

Questions on Making Successful Pathways with Carbon Disposal

DECARBONIZATION

- How can residual carbon creators be identified and allowed (or be shut down)?
- How can disposal be allowed without creating a loophole to make excessive CO2?
- How will the public understand that their sacrifices are not being exploited by carbon creators?

DISPOSAL

- How can quality and longevity of carbon disposal be insured?
- What will be the economics of carbon utilization and carbon storage?
- How can the state insure adequate provision and uptake of carbon disposal technologies?

COORDINATION

- How can residual carbon creation and carbon disposal be balanced in practice?
- Might individual residual carbon creators be forced to link to specific carbon disposers, or might it be managed in aggregate?
- How can "leakage" of importing cement, glass and steel from out of state be managed?

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BRIEF # 4

PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

Should I Stay or Should I Go? The Challenge of "Leakage"

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses findings that emerged through a series of interviews held in the spring of 2021, and a virtual workshop held in June 2021, in which over 115 stakeholder participants discussed Pathways to Carbon Neutrality in California.

Driving Carbon Producers Out of State Doesn't Solve the Problem.

Achieving net zero carbon by 2045 will require changes to virtually every aspect of California's economy. To the extent these changes affect the industrial and business sectors, there is a risk that this energy transition could cause "leakage" by motivating private sector entities to move some activities out of California.

MANY PARTICIPANTS SPECIFICALLY identified leakage as a risk. When business activity moves out of California, the emissions simply move to another location, and there is no overall reduction in carbon. As one participant put it, driving emissions out of state doesn't solve the problem.

Leakage is not specific to decarbonization. Businesses have long argued that California's regulations, costs, taxes, traffic, etc. make doing business in California so unattractive that some firms will choose to leave the state. Economists have debated these issues without achieving consensus, and the energy transition will add much (non-fossil) fuel to those fires. Our purpose in this brief is not to participate in this debate, but rather to identify specific areas where decarbonization policy and subsidy design might increase the risk of leakage.

DECARBONIZATION HAS POTENTIAL TO INCREASE LEAKAGE PRESSURE

If the consequences of decarbonization were to cause a business or business activity to become uneconomic, that business could not long remain in California. If the consequences were to cause a business or business activity to become less economic, that business may choose to leave California in order to retain acceptable profitability. ***Is the risk of forcing some business activity out of state being adequately considered?***

LOWER STANDARDS IN OTHER STATES

If a business activity moves to a region with lower efficiency standards than California, carbon emissions of the activity might increase. In addition, other states tend to have higher percentages of fossil-fired electricity than California, further increasing emissions. Products produced in another state for California would still be shipped into California thus increasing transportation carbon emissions. ***Is the risk of increased emissions in other states and related transportation activities due to leakage being adequately considered?***

SPECIFIC LEAKAGE RISKS

Listed below are some leakage risks identified by participants.

HOMEBUILDING

It is well-known that California is not building enough homes. Participants indicated that it is much easier to construct new housing in other states, and that, for example, a builder's return on investment in Idaho (which has much lower carbon standards than California) is almost 3 times higher than in California. ***Can the energy transition catalyze efforts to make homebuilding more attractive in California?***

POPULATION

Participants pointed out that when a person moves out of California, which has relatively low carbon emissions per capita[1], their carbon usage is likely to increase. Policies that make California less attractive to live in are problematic for overall carbon reduction. ***Is the challenge of homebuilding and risk of population loss or stagnation being adequately considered?***

TRUCKING AND WAREHOUSING

Participants indicated that the trucking industry has faced sustained pressure to replace diesel trucks with more expensive natural gas or electric vehicles. In southern California the warehouse industry faces costly mandates related to the number of diesel truck trips. The possibility that trucking and warehouse firms will accelerate the movement of California-serving operations to just over the state border merits consideration as decarbonization moves forward. ***Could regulations and subsidies for trucking and warehousing be designed and coordinated to achieve carbon and pollution goals while minimizing disruption to firms?***

FARMING

Participants indicated that many forces are reducing farming in California, with some farmers leaving even though "the land is harder to farm" in some other states. Participants indicated that these forces include high labor cost, high equipment cost (partly due to California-specific regulations), regulations (especially CARB), development pressure on farmland, and water shortages. Participants stated that small farms are the most vulnerable because they find it more difficult to address the regulatory burden.

DAIRY FARMS

Participants noted that dairy cow numbers are decreasing in California because the cows are moving out of state. Participants perceived that anaerobic digestors needed for decarbonization face excessive permitting and integration challenges (too many permits from too many agencies; too difficult to link anaerobic manure gas production into natural gas infrastructure). Participants expressed concern that because big dairies have economies of scale, the government is in effect subsidizing large dairies to get bigger.

BEEF RANCHING

Participants indicated that cattle need to be processed near where they are fattened up, but that California has been "leaking" processing plants for years, causing "many cattle" to be shipped out of state for slaughter and then shipped back for consumption. ***Are the cumulative impacts on farming and ranching being adequately considered?***

CEMENT

Participants pointed out that cement is an internationally-traded commodity, and if decarbonization substantially increases costs, cement production will likely leave the state. ***Is the impact on the cement industry being adequately considered?***

1 We note that CO_2 emissions per capita in Texas are 2.7 times higher than in California (2017 data).

Leakage in the Future

Leakage has and will continue to shape California's economy. The energy transition might cause additional unexpected leakage of business activity. It is difficult to predict in advance, or to prove in retrospect, the extent to which business relocations are caused by decarbonization. ***How can the potential for leakage be balanced with other factors as decarbonization proceeds?***

PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

Engagement Should Be More Inclusive

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses findings that emerged through a series of interviews held in the spring of 2021, and a virtual workshop held in June 2021, in which over 115 stakeholder participants discussed Pathways to Carbon Neutrality in California.

Broaden the Conversation to Broaden the Impact.

The transition to net zero carbon will touch virtually every aspect of California's economy and day-to-day life in every corner of the state. Broad engagement and support will be critical to success. However, several participants shared perceptions of lack of consultation, not being heard, or their opinions simply not mattering. Many participants indicated that they valued the interview and workshop process as an opportunity to be more fully heard. Some participants opined that "we need more workshops like this", indicating they value a venue where people from a multiplicity of backgrounds could share information, perspectives, and concerns.

INSUFFICIENT BROAD-BASED INVOLVEMENT from a variety of constituencies may pose a risk of making net zero carbon more difficult to achieve. This brief considers the following question: ***How can all Californians be substantively engaged in planning the changes for the transition?***

We discuss constituencies where participants perceived there may be insufficient inclusion in the vision or planning for achieving net zero carbon[1].

RURAL CALIFORNIA

California's government, regulators, higher education institutions, and nexuses of professional employment, as well as the main body of state decision-makers are centered in urban or suburban areas with relatively mild winters. Some participants perceived that there is insufficient focus on rural areas of the state. In rural areas, distances are greater and services are fewer. As one participant put it, "things look different if I'm in the country on a gravel road a mile from my mailbox with propane heat". ***Might the perspective of California's rural population be better incorporated into planning?***

HOME HEATING

Californians in (mostly rural) less-temperate climes experience sustained frost and snow in the winter, so reliable heat is critical. Participants expressed skepticism about 100% electrification of home heating in remote areas. ***How does the need for reliable heat affect prospects for electrification in rural areas?***

TRANSPORTATION

Participants raised concern about transportation reliability, in particular cars (due to the paucity of rural transit), especially in cold weather. Participants pointed out that a sudden wildfire evacuation makes transportation reliability a life-safety issue. ***How does the need for reliable transportation affect prospects for electrification in rural areas?***

RELIABILITY

Participants pointed out that California's rural areas can lose electrical service due to public-safety power shutoffs, grid damage caused by wildfires, and other reasons. Participants recognized that this increases rural concern about the electrification. ***How does the challenge of electrical reliability affect prospects for electrification in rural areas?***

1 In addition, we have identified that the interview and workshop process would have benefited from participation from rural government, and the fire service.

RURAL LOW-INCOME

Energy and air-quality regulators in California have long understood that they have a duty to ensure that the needs of low-income people are met. Some participants perceived that the focus tends to be on low-income people in urban and suburban areas, and that the challenges faced by low-income people in rural areas may be overlooked. ***What are the particular transition challenges faced by low-income people in rural areas?***

SOCIAL JUSTICE

Many participants recognized the importance of addressing social justice considerations as California moves to net zero carbon. This constituency was not well represented in the interviews or workshop. Several participants pointed out the challenge of understanding what social justice means, and in particular, it is difficult to identify who speaks for social justice. Some participants perceived that air quality is a greater concern than carbon, and raised concerns about the siting of gas-fired power stations (perceived as disproportionately located in low-income areas) that may be needed to bridge the transition to 100% renewables. ***How can social justice concerns inform planning for the transition to net zero carbon?***

BUSINESSES

LIVESTOCK INDUSTRY

Participants involved with the livestock industry indicated that they want to be part of the solution, but they feel unsupported in making certain beneficial changes. In particular, the process for funding, permitting, building, and connecting manure digesters to the natural gas infrastructure is perceived to be too complicated. Concerns were expressed about premature claims for feed additives, and a need for R&D to better deal with dry manure. ***Is there an opportunity to better engage with the livestock industry to find workable solutions?***

SMALL BUSINESS

Participants indicated that small businesses can struggle with complex regulations, grants or subsidies, or to address legal and regulatory measures. This can be because they lack the people or money to figure out how to deal with the technical issues associated with these regulations. The fragmentation of programs and requirements is a contributing factor in this difficulty. ***Can steps be taken to make it easier for small businesses to engage with regulations and subsidies?***

REGULATORY OVERLOAD

Almost all participants were clear that they want to be part of the solution. Participants shared experiences and frustrations with multiple regulatory bodies imposing burdens, seemingly without regard to the cumulative impact. One example is in trucking, where participants reported having to change out perfectly good diesel trucks for expensive natural gas trucks. They were then told to replace the perfectly good natural gas trucks with expensive electric trucks due to changing standards with regards to warehouses. Participants also expressed frustration that "we can't do things that other jurisdictions do". ***Is there opportunity for regulation and subsidies to be re-engineered, and/or integrated across agencies to streamline adoption by businesses?***

People are the Key

Asking people to change their behaviors is hard. As one participant put it, "normal people are the key, and we have to get them to change". For example, participants said that "people want to run their dishwashers after dinner", or "drive their ICE car until it fails". Some people will either have to be incentivized to change, or the net zero carbon system will have to accommodate their desires. ***Are there opportunities for better engagement with the general public?***

BRIEF # 6

PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

Time is of the Essence

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses findings that emerged through a series of interviews held in the spring of 2021, and a virtual workshop held in June 2021, in which over 115 stakeholder participants discussed Pathways to Carbon Neutrality in California.

2045 is Closer Than You Think

California has the goal of achieving net zero carbon by 2045, leaving only 24 years to get the job done. That might seem like plenty of time, but there is much to be accomplished, some of it unprecedented in scale and scope. We observe that the net zero goal requires essentially reengineering most of California's energy system, entailing profound transformations to infrastructure, land use, and behavior.

THE CHALLENGE OF BUILDING IN CALIFORNIA

Many participants expressed the sentiment that it is difficult to build in California. Observing China's electricity expansion, one participant believes that the "build out is physically doable" but "it takes too long to build things in California". ***Can California build quickly enough to realize decarbonization goals in 24 years?***

Participants noted that an infrastructure project that can be built in "a couple of years" in Texas takes "at least five years" in California due to regulatory review. ***How can California ensure that regulatory and governance mechanisms can enable the infrastructure necessary for decarbonization in 24 years?***

Existing regulatory structures are devised for the existing system. Participants are not optimistic that these structures will be able to accommodate the dramatic buildout and upgrades required for electrification. ***How will a regulatory system that is meant to manage incremental change handle what amounts to reengineering the entire system?***

UNDERSTANDING THE CHANGING ENERGY LANDSCAPE

The current way of doing things is well-established. This includes permitting, conducting environmental impact analyses, and modeling electricity and, more broadly, energy systems. These systems are changing and the pace of change will be increased by decarbonization. ***How can California's systems for understanding, evaluating, building, and regulating energy systems enable decarbonization in 24 years?***

The conversion of residential and commercial fossil-fuel appliances to all-electric, and of transportation and industry from fossil-fuel systems to all-electric will cause changes to the nature and timing of loads. The advent of consumer-owned generation and storage is changing the nature of the load curve. The retirement of most fossil-fuel generators while at the same time substantially increasing the grid to meet new transportation, buildings, and industrial demands will impact economics, reliability, and resiliency.

Does California have adequate understanding and appropriate analytical tools to address the future nature and performance of electricity infrastructure?

THE ROLE OF INNOVATION

California is famous as a source for innovation, and innovation of all aspects of the electrical system will be important for decarbonization to succeed. One optimistic participant stated "we are going to innovate our way out of this", meaning that new solutions and technologies must (and will) be discovered, commercialized, and deployed. ***Is California prepared to rapidly evaluate and exploit innovations that have not yet been invented?***

THE RISK OF MOVING GOALPOSTS

Setting goals in the face of technological and economic change is inherently challenging. Ambitious goals can stimulate the creativity of the private sector and attract investment. However, overly ambitious goals can create unrealistic expectations and inevitable recrimination. This dilemma may become more challenging.

GOALS CAN BE CHANGED, WHICH CAN CAUSE SEEMINGLY GOOD INVESTMENTS TO BECOME USELESS

Participants point out that when change happens, sometimes "the goalposts move away" meaning that regulators change the rules of the game such that long-term investments based on one set of rules can be harmed or rendered uneconomic. Participants point out that this can undermine support for the purpose underlying the goals.

Goals can be changed when unobtainable. Participants indicate that regulators will posit aggressive goals to incentivize innovation and investment. But if it doesn't work out, they will "move the goalpost back" and declare victory. However, this won't work for the state's net zero decarbonization goal. ***How can California set expectations that enable firms and consumers to invest and support decarbonization in 24 years?***

ELECTRIC VEHICLES

California has about 14 million internal combustion cars. If proposed transportation goals are to be met, they will all need to be replaced by electric vehicles. These additional electric vehicles will need to be charged. Participants point out that this will require a massive increase in the number of charge points, which need to sited, permitted, built, and supplied with electricity. Providing EV charging for people without garages or with inferior wiring poses challenges. A participant with knowledge of the trucking industry reports that it is very challenging and slow to try build a charge point at a truck depot. ***How can California provide large-scale EV charging capability in a way that works for all people and businesses in 24 years?***

RESIDENTIAL RETROFITTING

California has around 14 million existing residences. Almost all use fossil fuel for space heat, hot water, and cooking. These residences will need to be retrofitted. Many existing residences have financially-attractive opportunities to increase energy efficiency, but have not been retrofitted. Participants point out that the scale of this challenge is unprecedented. ***How can California decarbonize millions of residences in 24 years?***

INCREASED ELECTRICITY GENERATION

Net zero requires that consumers and businesses replace most fossil fuel usage with electricity, necessitating significant amounts of new generation. Participants estimated that California's electricity consumption will at least double.

MASSIVE BUILDOUT OF SOLAR AND WIND

California will need to build renewables both to meet the new demand and to replace existing fossil fuel generation. Based on current costs, this will be dominated by solar and wind. Participants indicate that due to climate change (long term drought), hydropower may be less available for electricity generation, and that new renewable resources will require "a lot of sites in a lot of places" with a "sizable physical footprint". ***How can California ensure that enough land (and sea) is dedicated to renewables in 24 years?***

BUILDOUT OF ELECTRICAL TRANSMISSION LINES

Participants point out that there are potential large-scale renewable generation opportunities offshore, in California's southern and southeastern desert areas, and in other states as far away as Wyoming. That electricity must be transmitted over significant distances to load centers which are primarily in urban areas, necessitating the construction of new transmission lines and/or upgrade of existing lines. Participants view this as very challenging, with one stating "many have tried and failed to build transmission", and indicate that acquisition of right-of-way and obtaining permits from multiple jurisdictions is particularly difficult and time-consuming. ***How can California ensure that enough transmission is built to enable electrification in 24 years?***

INTERSTATE RENEWABLE ELECTRICITY TRADING

Participants indicated that it can be very attractive to use renewable resources from other states, not only because they can develop capacity, but because the timing of wind to the east may align with California's electricity demand. Some of California's goals may be impeded by other states' own renewable goals, which could limit California's access to this generation during peak periods, such as regional heat waves. ***How can California coordinate with other states to ensure renewables supply in 24 years?***

UPGRADES TO ELECTRICAL DISTRIBUTION SYSTEMS

As demand increases from the growth of electrical vehicles and residential conversion from fossil fuels to electricity, distribution systems will require upgrades. This will include new and additional transformers to handle peak demand for charging EVs, etc. ***How can California manage and implement distribution modifications to enable electrification in 24 years?***

ADVANCES IN SECURE SYSTEM MANAGEMENT

There will be a need for development of cyber-secure system management technology – telecommunication systems, monitoring and measurement devices, artificial intelligence – to address peak demand, peak generation and load shifting on a distributed system level. ***How can California develop and deploy new, cyber-secure distribution management systems?***

Much to Build and Not Much Time

Participants noted that much remains to be done to ensure that California has the ability to identify, plan, permit, construct, and commission massive infrastructure projects across much of the state's economy, geography, and jurisdictions.

Our observation is that if we knew everything to do, we'd still have to do it – which is a daunting challenge; the challenge is greater because we don't fully understand what is to be done.

Report Introduction

California leads the nation and much of the world in policies to mitigate climate change. The state has near-term goals of 40% emissions reductions (relative to a 1990 baseline) and 60% renewable electricity by 2030 (SB100 and AB32); it has a long-term target of net zero emissions by 2045 (EO B-55-38), and SB 100 mandates that California achieve a net-zero carbon electricity grid in 2045 by meeting all retail sales of electricity from clean resources, not necessarily limited to certified renewable resources. More recently, two new Executive Orders have been announced to further combat climate change. EO N-79-20 bans the sale of new gas-powered cars and trucks by 2035 and EO N-82-20 establishes the goal of protecting 30% of California's lands and waters by 2030. State agencies are now required to come up with a plan in the next year to "accelerate natural removal of carbon" and store more carbon in the state's soils.

This report summarizes insights from a series of interviews conducted in the spring of 2021 as well as a workshop conducted in June 2021. This report does not represent the views of Stanford University or the project sponsors. The intent of the Stanford project team was to obtain perspectives from across a wide range of organizations in government, the private sector, and academia. The Stanford project team tried to bring together these many groups to help create momentum in addressing the climate change crisis. While it may not be possible to bring in all groups under a "big tent" to support all carbon neutrality goals, the Stanford team believed that by giving voice to as many sectors as possible, everyone would have a better understanding of the goals, the difficulties in reaching those goals, and the new mechanisms needed to overcome those difficulties.

An early part of this effort was to conduct a series of interviews to obtain a sense of how different sectors within California viewed its carbon neutrality goals. Forty-seven interviews were conducted between January 2021 and April 2021. The interviewees included government officials and managers, private business leaders, university and national laboratory researchers, trade and labor associations, and non-governmental organizations, as illustrated in Table 1. These interviews were not taped nor does this report assign attributions to specific individuals per their comments. The interview process involved expert elicitation[b] employing a semi-structured interviewing method coupled with referral and theoretical sampling approaches to gather practitioner perspectives on California's carbon neutrality goals. The team attempted to span the space of organizations that connected to the challenge and identify senior leaders for input, supplemented by additional interviews as we learned more about additional organizations or experts who had escaped our initial scope.

[b] Expert elicitation refers to formal procedures for obtaining and combining expert judgments. Expert elicitations typically include multiple experts to capture diversity of knowledge, background, and opinion [9]

	Interviewee/Stakeholder Type					Total
Sector	Private Business	Trade Organization/ Labor groups	Government	Academia/ National Labs	NGOs	
Electricity	7		3	6	2	18
Transportation	6	1	2			9
Industry		5	1			6
Buildings		2	1	1	1	5
Livestock/Ag		3				3
Other			4	3		6

Table 1: Summary of stakeholders interviewed for analysis by sector and stakeholder type. Note that some interviews have more than one interviewee.

The insights from the interviews were highly useful in framing the discussion for the follow-up project workshop held in June 2021 by informing project leadership as to how to develop a workshop that further explored aspects of carbon neutrality from the standpoint of government, labor, academia, industry, and trade and labor associations. The workshop was divided into the following 4 sessions:

- Pathways to Carbon Neutrality in California – A Sectoral Perspective
- The Carbon Neutral Grid
- Business & the Private Sector in a Carbon Neutral California
- Social Equity and Jobs in a Carbon Neutral California

Each session at the workshop included a 5 to 6 very short (5-10 minute) presentations followed by at least one hour of group discussion. Participants in the workshop included 17 individuals that were previously interviewed, plus many additional participants as noted in Table 2.

	Attendee/Stakeholder Type					Total
Sector	Private Business	Trade Organization/ Labor groups	Government	Academia/ National Labs	NGOs	
Electricity	3		2	2		7
Transportation	1			4		5
Industry	13	10	1	1		25
Buildings		4		2		6
Livestock/Ag		1		3		4
Other		1	6	11	3	21

Table 2: Workshop participant breakdown by sector and stakeholder type. Counts do not include participants that were previously interviewed and listed in Table 1.

The workshop and interview insights will be used in the next phase of the overall project which consists of "deep dive" analyses into the following eight areas:

- Electricity
- Transportation
- Residential
- Commercial
- Industry

- Hydrogen
- Bioenergy
- Forest Management

The sections of this report are divided into categories based on commentary from the interviews and workshop. The sections that follow are:

I. California Policies
II. Regulation
III. Electricity
IV. Transportation
V. Buildings and Energy Efficiency
VI. Industry
VII. Natural Resources and Agriculture
VIII. Socioeconomic Aspects of Meeting Carbon Neutrality Goals

A final section offers some insights into some conclusions and next steps. While some of the commentary may seem critical of state policies and regulations, the intent is to provide systematic integration of thoughts across a broad spectrum of California. In this context, the goals of the project are not to be excessively critical of state practices. Rather, the intent is to provide a basis for broader segments of the state to work together to achieve its carbon neutrality goals.

Section I: California Policies

"There is a fixation on 'Big Announcements' related to policy rollout. The state is not so good at implementation planning."

"Being a leader is fine, being a leader at expense of the economy is not fine."

"If you are seen as a leader and turn around and no one is following, you are not a leader, you are an outlier."

"Energy policy in CA is more religion than rationality"

"Political appointees that do not know a lot about power systems and energy markets, are politically connected and electrically disconnected"

The title of the June workshop was "Pathways to Carbon Neutrality in California: Clean Energy Solutions that Work for Everyone". Many participants noted both during and after the event that the forum provided a venue for disparate groups to come together to discuss carbon neutrality goals and how to achieve them. A recurring question was "Why can't the legislature be involved in similar discussions to those we are having today, and then pass laws? " There was considerable commentary concerning the seeming disconnect between policy development and implementation. Effective policy implementation requires a coherent strategy, engagement of disparate groups across the political spectrum, and successful implementation of interim goals. The current legislative process is not conducive for designing solutions for everyone.

There is tension between rules that have been passed by legislature and state goals. There needs to be better clarity on what counts as a renewable technology and resource. The definition of carbon neutrality needs to be solidified to help define the difference between net zero emissions and absolute zero fossil use. The goals should be more specific on how to achieve carbon neutrality and what the time frame will be. The state should stop developing goals that can result in lots of penalties, if they are not met. This makes the challenge harder in getting the various sectors to work together.

To be carbon neutral by 2045, legislation, planning and implementation need to be coordinated and accelerated. If the state doesn't move proactively, investments will - in the shorter term - be costlier and provide less-effective solutions. This includes additional development for and upgrading of transmission lines. Distribution planning and customer planning will become more important and must be incorporated into overall system planning. California will need to make use of new and emerging technologies that are either not invented or are not cost effective enough to be commercialized in the near term. Renewables in California are relatively plentiful and low cost. The state needs to continue their implementation, but also continue to ensure that grid reliability issues are addressed.

There are potential unintended consequences as a result of new policies. We need to provide for analysis and planning for these unintended consequences. We need to spotlight these issues. If not, the middle class will begin to move out of the state. Market incentives

are needed to provide a competitive environment. If reducing emissions reduces jobs and just shifts emissions out of state, that doesn't help. "Put it on a level playing field so that consumer choice can help us find the best choice for decarbonization."

CARB should rethink and manage the decline of the oil supply produced in the state. Just because state-wide production is reduced doesn't mean that emissions are going down, since the likely import of product will occur to match supply needs. California should have no interest in shutting down refineries and then importing from less clean refineries. Only shut them down when they are ready to get shut down, when there is less demand.

As part of a galvanizing vision, a grand strategy should be linked to previous "grand visions," i.e., the "Race to the Moon" and the development of the Interstate Highway system as part of defensive preparedness. Couching the strategy in these terms provides a relationship to visions developed over fifty years ago that ended up requiring substantive amounts of funding, broad consensus, and the development and expansion of the workforce. This vision requires an expansion of the social safety net as some trades will no longer be needed. At the same time, the state should consider doing away with subsidies for the purchase of certain technologies (i. e., electric vehicles, rooftop solar) that are already commercial and in practice simply supply government subsidies to richer parts of the state. In addition, some interviewees pointed out that many policies and regulations are developed in an "echo chamber." That is, like-minded people develop these rules and policies without considering how these rules and policies impact others – effectively producing elitist solutions.

This vision must necessarily involve developing close ties to relevant industries in order to effect change. This is because the massive scale of change, particularly for electricity, is not widely understood. It is estimated that the grid will need to grow to more than two-and-a-half times its current size, while simultaneously being decarbonized. Thus, incremental government investments will not achieve the goals of the state. At the same time, the state should be as aggressive as possible in terms of developing energy efficient technologies and regulations to reduce the need for more electricity. Significant non-carbon dioxide benefits can accrue due to significant reduction in air pollution, which in turn will support improved environmental justice goals.

The state is likely to be constrained in its ability to rapidly build necessary new infrastructure. Particularly challenging will be the permitting, construction, and upgrading of new and existing transmission lines. In addition, millions of charging points will be needed for electric vehicles. There will be a need for distribution upgrades to serve them. An open question is "who will pay for distribution system upgrades?" Improperly planned approaches to resolving these issues could lead to much higher costs for end-use electricity users.

There were concerns that implementing carbon neutrality goals could inhibit economic development in California. The state emits less than 1% of world greenhouse gas (GHG) emissions and actions taken to reduce them will not solve the global problem. What does matter is the state's impact on the rest of the world. If California's decarbonization is too expensive then no one is going to follow. If the state's universities and national laboratories develop new technologies, California can make a significant global impact. Thus, one

interviewee pointed out that the state is missing the point per its goals, it should be developing technologies to export to other countries.

We need more education in civics. People need a better appreciation of how government works. Trust increases when we have our best and brightest in government and public policy.

And finally, commenters believe that the state lacks a consensus, despite the laws and regulations that have been enacted and promulgated. Following consensus, the state must get involvement from all relevant organizations to meet its carbon neutrality goals. A comment was made in the interviews that "the goalposts are moving." There will be a need to overcome business-as-usual approaches.

Section II: Regulation

"Regulatory Goulash - Governance highly decentralized and siloed with Boards, Commissions, State Treasurer, etc., independently elected or appointed."

"Regulation/Governance/Planning are structures created for a legacy system that is going away; why would we expect them to perform well for a radically new system?"

"California regulatory perspective is if you mandate it, they'll build it."

"The solution is always more regulation, not less"

Regulatory governance will be of increasing concern. Can the legal and regulatory structures accommodate massive build-out in short time? This issue was raised by a number of interviewees – both those supporting aggressive carbon neutrality implementation and those preferring a more measured approach. The regulators are seen as being fragmented. The grid is balkanized due to multiple decision makers – the California Independent System Operator (CAISO), investor-owned utilities, publicly-owned utilities, community choice aggregators, etc. Marginally optimal decision-making is not appropriate for a massive infrastructure transition. This fragmentation also will allow for the proliferation of lawsuits to delay implementation advances.

There was considerable commentary about the "balkanization" of California's regulatory system. A number of interviewees noted the (not necessarily good) dynamic between the various state agencies. There is a need to have alignment within and among the different government agencies. It needs to be clear to everyone which agency is in overall charge of any process so that it will be clear who is accountable. There is also a need for review and oversight processes. In other words, using lessons learned, the system can be made to function more effectively.

As quoted above, much of regulation was seen by those regulated as a "soup." The California Air Resources Board (CARB) and the California Energy Commission (CEC) do not appear to be communicating. It is perceived by those outside government that there is a continual fight for budget among the agencies based on different programs the agencies run that may be somewhat opaque to the general public.

There were comments about the risk of low morale in agencies at a time when transition to new operational systems is happening quickly. As noted in the previous section, the Governor's Office and the Legislature pass laws that are the basis for progress toward decarbonization goals. However, it can be difficult for state agencies to keep up with new policies and to assess how these policies might impact the private sector entities that are attempting to meet these policies. It is difficult for applicants for grants, subsidies, and rebates due to the "maze of websites" - all done differently by different agencies. As an example of "dueling rules," CPUC Energy Efficiency Proceeding funds $100M of equipment and is based on societal cost/benefit, but also incents natural gas. CPUC Building Decarbonization Proceedings incent electric. Thus, there is a need to "future proof" CPUC

proceedings to align Codes and Programs. And while CARB's cap-and-trade program is deemed a success, the funds are not being used to support programs for GHG reduction.

A number of agency interviewees mentioned that, under the circumstances, they have done a lot really well. However, severe governance challenges related to coordination remain. There is a lot of talent within state agencies, but much of this experience and expertise is siloed. A number of interviewees, both in government and private sectors, commented that "CARB does its own thing" and doesn't necessarily respond to any other authority. "CARB will put a stake in the ground, force action/spending, learn it won't work, and then move the goalpost back and declare victory."

Much of state GHG strategy is coordinated by CARB, particularly in transportation, but is disconnected from much of what is happening economically and from an electricity perspective. To that end, CARB is not seen as technology neutral, but rather promotes EVs without considering other forms of renewable transportation, such as fuel cells and "green" hydrogen. And, as mentioned in the previous section, EV subsidies are seen by some as "dollars for white folks." CAISO, by its very nature is a private corporation that must ensure that California's grid is reliable and resilient. To that end, the California Public Utility Commission (CPUC) develops long term strategy, but is not necessarily connected to the scale of CAISO's operations and mandate.

Most regulatory and legislative mandates are seen by those to whom they apply as burdensome in a way that is not appreciated by governmental personnel. Entities that must comply with these mandates believe that many that are developed are poorly thought out. There can be a tendency to implement new rules, with impacted stakeholders being consulted afterwards. Because of this, these new mandates are often drafted with insufficient comments from impacted organizations. Additionally, there was broad agreement in the workshop that the CEQA process needs to be streamlined. This process is important, but should be timelier.

Further, some of these rules may have "unintended consequences." That is, while achieving one goal, another possibly more significant problem arises. These unintended consequences can sometimes impact lower-income communities. An interviewee observed that the developers of laws and regulations are in a different economic class than many Californians and, as a result, do not understand the impacts of these rules on various Californian communities.

Industry leaders are unsure of how to proceed as regulatory and technology uncertainties cause them to pause in making new investments. They remain skeptical of cost/performance forecasts until proven and lack confidence that promised state or federal subsidies will appear. Due to potential for rapidly changing regulations, industry worries that investments will not be allowed to achieve planned economically useful life. This leads to forced divestment of useful assets. Some industries feel they are in a regulatory "whipsaw" between CARB, Air Quality Management Districts (AQMD), and Port Authorities. Some of these new rules are in conflict with one another. For example, warehouse and trucking companies have been pushed to purchase compressed natural gas (CNG) vehicles due to

changing warehouse emissions regulations. This could preclude their ability to economically purchase EVs prior to the end of the useful economic life of the CNG vehicles.

Citing another example, one interviewee noted that too many permits (from the Farm Credit Association, CalEPA, CPUC, CARB, etc.) are necessary for implementation of anaerobic digestors and "Regulators don't care, we just have to deal with it." An appropriate reality check would be, "are new rules cost effective and do they provide value for the industry to maintain." Also, regulations should ensure that consumers will accept the end product and that there will be manufacturers who can develop and sell the technologies at a reasonable price.

California electricity retail rates are extremely high, not because the marginal rates of supply are high, but because the state has bundled so much on to the rates. The state is trying to reduce marginal cost of generation, but most of the rate is used to pay fixed costs. Some alternatives could be income-based fixed charges that could be subsidized in the state budget. The state could use low income program budgets to help pay for rooftop solar subsidies instead of rates. Certainly, high rates are one of the reasons rooftop solar industry is so successful. It was suggested to use Performance Standards not just Prescriptive Standards[c], although Prescriptive Standards may be needed for small businesses who can't handle complexity.

Better partnerships between cities and other local governmental agencies with state agencies would also be helpful. Most GHG regulation is under local control in terms of housing and building codes. An example is the ban on new natural gas hookups in some municipalities. There is a need to converge and integrate urban planning with electricity distribution planning and decarbonization. There should be collaboration between various regulatory entities to reward GHG reduction in terms of incentives. The CPUC 2022 Energy Code is supposed to do that.

Regulations aren't always well enforced, which penalizes good businesses who take on the cost of meeting regulations. There's a need for streamlining compliance and permitting for big projects. Tax policies need to be aligned to encourage R&D. More investment in public-private partnerships and technical training is needed. The state needs to develop policies to invest in more diversity for creating a diverse future workforce.

It simply takes too long to build things in California. For example, a new gas plant in Texas takes 2-2.5 years to build, while one in California takes 5-7 years and costs more. For buildings, California has the most innovative and restrictive rules and codes, which the rest of country's building industry wants to avoid. The concern, which will be taken up in other chapters, is that industry may leave the state due to the high cost and considerable time needed to meet the regulations.

[c] A Prescriptive Standard requires each component to be built to a certain standard. A Performance Standard requires that the building or system as a whole performs to a certain standard.

Section III: Electricity

"We are seeing the fruition of high-level policy goals set in the early 2000s"

"Many have tried and failed to build transmission"

"Energy efficiency doesn't kill people the way that power failures do"

"Electricity Transmission and Distribution are increasingly coupled"

"Don't do an experiment on reliability during the transition"

"Contingency has value"

"Is electrification really the answer to everything?"

"Can't electrify everything if electricity is too costly"

There is a significant breadth of opinions concerning the ability of the California grid to reach carbon neutrality. One area of agreement is that the electrification of transportation, industry, and buildings will be transformative and require substantially more electricity than what the state now uses. "All the eggs are in the electricity basket." There were interview and workshop discussions on whether the goal should be zero carbon emissions or 90% carbon-free electricity. There is an emerging consensus that 90% of the grid powered by renewables is possible. However, how the state gets the last 10% without offsets is uncertain. Leaving the renewable energy goal at 90% rather than 100% changes options. A number of commenters suggested that a 100% policy will limit the state in achieving its carbon neutrality goals. California needs to consider more choices in developing firm power for the grid. Other commenters disagreed, pointing out that there are many organizations that would want to "squeeze" into that last 10%. There is consensus that to get to 100%, the final 10% would be challenging.

There are a number of challenges facing California in a carbon neutral future. There will be considerable difficulty in expanding transmission (resource pooling, reliability, resilience, deliverability to loads). Infrastructure must be developed on a large scale in order to serve all the energy uses that will be electrified. There is no utility or CAISO control over all assets affecting the grid, particularly distributed assets.

To move forward on reducing carbon emissions from the electricity grid, flexible approaches are needed that incorporate a diverse set of solutions. A willingness to explore and implement the technologies of tomorrow will also be needed. This requires a stable, supportive state energy policy. Given the magnitude of projected electricity growth, these new approaches must start immediately.

It is important to note that, as one workshop presenter pointed out, there are more immediate concerns about California's electricity grid. California's peak demand for energy has been shifting from an afternoon peak to one in the early evening when solar is not

available. However, energy capacity on the grid is decreasing due to net retirement of 3,700 MW of gas-fired generation and the 2200 MW Diablo Canyon nuclear facility. Imports are tightening and load is climbing.

The state regulator has authorized 3,300 MW of additional procurement, and the California Independent System Operator (CAISO) recommends an additional 10,000 MW in an ongoing proceeding [1] [2]. The concern is that, if natural gas combined cycle generators are retired and nuclear and abundant hydro are absent in the global warming future, there will be no long-term zero-carbon firm resources available to the electricity grid. Thus, there may be a need to re-examine existing, but ineligible, carbon-free energy sources, such as nuclear.

Planning

Substantive integrated planning and implementation approaches will be needed. The scale and scope of new systems will be different from existing legacy systems. There is currently no agreed-upon approach for how this will be done. Planning capabilities are diverse as they are conducted by CAISO, CPUC, investor-owned utilities (IOUs), Public Utilities (POUs), and community choice aggregators (CCAs). There are concerns about coordination issues between system-wide operators, such as CAISO, CPUC planning activities, utility operations, and CCAs making decisions with a lack of overall coordination and communication. As one commenter stated, for California "as complexity increases, the number of cooks in the kitchen increases."

One interviewee said that utilities need to be engaged as they truly understand the grid. However, other interviewees stated that the utilities had no idea how they would reach 100% carbon neutrality. Specifically, there was a belief that the IOUs retain monopolistic attitudes incentivized by rate base planning that are impediments to policy goals. Thus, the IOUs have no interest in efficiency, low costs, or anything that threatens their generation assets (although it should be noted that California IOUs have few generation assets). Their current role should be further de-emphasized and be made to be "wires" companies. CCAs could become a countervailing force, although CCA exit fees to IOUs remain a challenge according to one interviewee. It was also noted that there is a span of effective to ineffective management among the CCAs. While CPUC has been given the task of leading the state Integrated Resource Planning (IRP) process, a number of interviewees thought that this was not the best use of the agency's time and capabilities.

Planning efforts need to address risks to the grid. To this end, interviewees believe that no organization is planning for the changing nature of the grid, nor for electrification of buildings, industry, and transportation. No one appears to be properly allocating for EV loads in long-term forecasts. Planning should focus on physical risks, related to climate change (wildfires, drought). Other risks are electrical - related to increased power flows and especially increased power flow volatility (high ramp rates). Remediations include more robust power lines, digital monitoring, and better controls. As an example, heavy nighttime residential charging may prevent transformers and other equipment from cooling off. This increases the probability of equipment failures, which is a known failure mode. When considering grid transformation, decarbonization must increase resilience to these and other threats.

Utilities need to plan and prepare for responses to cyber-security attacks on their grids. Smart buildings and appliances, inverters, and other communications devices provide pathways for cyber-attacks. Power systems are increasingly reliant on communications with distributed nodes. There is a need to develop a common, secure two-way communications infrastructure. However, these systems need to have security "baked-in," rather than attempt to develop security fixes after the fact. Infrastructure nodes need to be secure (e.g., home inverters) as new forms of inverters will allow for improved grid forming services in the future.

The changing grid requires new models to properly address these changes, "the goalposts are moving." Current production cost modeling tools might not apply well in the future. Non-dispatchable resources have new uncertainties, but also provide new opportunities for grid management. Since big industrial energy users are starting to produce their own renewable electricity (e.g., Google), new thinking and modeling are needed. There is a need for real-time decision-making tools that will optimize all variables while maintaining various grid services, such as reliability, resiliency, and cyber security. All system aspects will need to be aligned to reach state carbon neutrality goals.

A significant concern raised by a number of interviewees is that too rapid a build-out of specific renewables, for example utility-scale solar, can lead to a less diverse portfolio. Better planning and new planning models allow for evaluation and implementation of a more diverse mix. As an example, solar thermal was overbuilt which led to negative impacts (desert land) not previously understood. Costs didn't come down as hoped as photovoltaic price decreases harmed the economics of solar thermal.

Reliability in the Context of System Operations

During the workshop, there was an active debate concerning reliability issues. Some workshop participants think this concern is overblown. They pointed to times when the state was supposedly at 98% renewables, and there were no problems. Other participants think that the reliability issue is not overblown. With complex systems, things can go wrong. Building computer models doesn't keep the lights on. The more complex the grid becomes, the higher the chance that things will break in ways never considered. The state needs to plan for and understand potentially pervasive complex uncertainties. Risk planners have a different perspective on flexibility, with risk analysis and management being paramount. Risk managers from the insurance sector should be added to future discussions. "Unless we are lucky, we will find out in the future how bad we were in forecasting and planning."

As one interviewee observes, "there is a rush to renewables without thinking through the system changes that will be required for this transition." If given choice of "clean" versus "reliable", many would choose reliable to have a constant flow of electricity. Carbon neutrality must be co-optimized with resilience and reliability. As one interviewee said, "don't break it while you transition it." Reliability will increase in importance due to concerns about the reliability of intermittent renewable generation, even with energy storage. One interviewee believes that giving solar and wind reliability credit by using average production is based on politics, while solar and wind advocates argue that these resources should get reliability credit.

There will be a need for integrated approaches across procurement to ensure year-ahead and month-ahead resource adequacy for allowing an effective transition to higher renewable generation levels. Planning must include scenarios that will address emerging challenges and how to respond to them. For example, the amount of renewable generation that will be available during multi-day weather events will be difficult to predict. Current commercial storage is on the order of four- to eight-hour duration. There will be a need to have longer term commercial storage in the future.

New approaches must be taken for grid planning and operation. This includes addressing challenges created by retiring so much dispatchable, inertia-providing generation, while bringing on lots of less-dispatchable inverter-based resources. System operators must effectively manage a faster, more complicated grid, including the integration of many distributed and behind-the-meter resources with utility-scale resources. Rapid increases in demand or "ramps" are currently being met by natural gas resources and imported energy. These requirements for California may reach a ramping rate of 25 GW in three hours by 2030. California relies on natural gas resources and out of state power which may become less certain in the future as other states, such as Nevada and Arizona, attempt to meet their own renewable portfolio standard goals. Currently, analytical tools that properly address these issues are not available. These changes will necessarily lead to changing grid management requirements for meeting resource adequacy and resilience goals.

The proper management of reliability will need to change in terms of a paradigm shift under new operational conditions. The historical grid design was based on dispatchable resources that were primarily large centralized thermal generation units. California appears to be "squeezing" solar and wind into that paradigm, where solar and wind are not dispatchable resources, although utility-scale solar and wind can be curtailed. As increasing percentages of renewable energy systems come on line, just raising the reserve margin instead of making fundamental operational shifts may not solve the problem. Lack of reliability may undermine the incorporation of intermittent resources into the grid.

Because of reliability issues, there is a perception that utilities prefer fossil fuels. Renewable options for firm power include hydro, geothermal, solar thermal, and biofuels. However, geothermal is limited geographically and biofuels are of concern due to higher prices. Other carbon-free choices either have public perception problems and/or are currently limited by high costs. These include nuclear, CCS, and hydrogen. There is also a perception that solar + storage is a reliable resource. However, for longer-term weather-related problems, it is not sufficient.

One commentator suggested that, given that most intermittent renewables produce DC power, at some point the state may want to go to DC system rather than AC system. While there are DC technologies on a small level, the state must consider its broader interaction with the Western Electricity Coordination Council.

California can't do an experiment on reliability during the transition. A number of interviewees commented that closing thermal power plants, primarily natural gas combined cycle plants, too quickly would be mistake. It is essential to retain gas capacity as reliability insurance. One interviewee sees state gas capacity for California increasing by 2050 for

reliability reasons. There will be a need to educate legislators and the general public to differentiate between gas capacity – as needed for reliability – and utilization – to be avoided if at all possible. As with other issues related to grid transformation, the question will be to define who pays for standby gas capacity. Additionally, there will continue to be large fixed costs in transmission and distribution. With fewer customers, end user rates will increase to support fixed costs. This may lead to an equity risk for lower income families.

California does not need reliable baseload power, rather reliable and resilient fast-ramping dispatchable power sources. Workshop presenters and interviewees discussed the fact that baseload power, for example nuclear, cannot change generation output quickly. At minimum loads, a thermal generator needs to sell at negative prices, shut down, or force curtailment of cheaper renewable energy resources. The most useful natural gas generators will allow for very low minimum power operations, be very fuel efficient (reducing emissions), and have very fast ramping capabilities. A related long-term problem is demand versus supply. Given the new paradigm of high percentages of intermittent renewable resources, we need to stop thinking about how to manage supply and start thinking about how to manage demand. In the long-term, the value of grid reliability and ancillary services may be more valuable than the value of electricity as a commodity.

There is a need to assess operational reliability. There is no California (or for many other states) study that properly accounts for reliability over multiple years. Proper analysis will allow for a better understanding of what additional investments are needed for system reliability, including the development and implementation of appropriate reserve margins. Transition from a primarily central station, thermal based, dispatchable grid to one which is primarily powered by utility-scale and distributed intermittent renewables must be effectively managed.

Transmission and Out-of-State Power

Transmission expansion will require "Political Will." Movement of electricity from renewable resource generation locations – both in-state and in other parts of the West – to load centers (cities) will require substantive amounts of new transmission lines or significant upgrading of existing lines. Permitting across multiple political jurisdictions is very time consuming. At some point there may be a need to invoke eminent domain to build transmission lines in a timely and effective manner. This requires a determination that development of renewable resources and the attendant use of new transmission systems is a public good.

Siting decisions will be important for future in-state generation. California has passed the Desert Renewable Energy Conservation Plan. Despite its title, the emphasis is not on "renewable energy," but on "conservation." Thus, adherence to this regulation may inhibit some future development of renewable energy in the state. The state also has the Renewable Energy Transmission Initiative. The point of this initiative is to properly evaluate the transmission needs of the state in terms of bringing electricity from often remote renewable resources to urban load centers.

There was concern about the use of out-of-state power. While much reduced, California still gets up to 20% of its electricity in low-hydro years as "coal-by-wire" from other states. One

interviewee said that California was "too dependent" on imports and should reassess reliance on imports. However, as other states close coal-fired plants, there may be less capacity available for the state in the near future as these states pursue their own renewable energy goals.

A success story has been CAISO's development of the Energy Imbalance Market (EIM) with specific agreements between many entities across the West. EIM has provided $1.2B savings to electricity users in five years [3]. All ISOs follow the CAISO approach to dispatch least cost resources every five minutes and include transmission congestion in the optimization. There is an opportunity to unify dispatch on the whole western interconnect, but there must be better coordination across state lines. A governance review is underway with other states agreeable to regional governance.

California politics present a problem as "Newsom is listening to 'parochial unions', while the Legislature wants to control/influence the CAISO board," which is FERC regulated. Carbon neutrality in California has implications for other states, such as Nevada and Arizona. California can't reach its carbon neutrality goals without other states having carbon reduction ambitions of their own. There is a perception amongst some that Western states do not want to "play" with California.

Distributed Systems and Comments on End Users

This section considers a number of interrelated items concerning the distribution system. Folded into this discussion are topics including demand response (DR), energy efficiency, impact on lower income families, job creation, and microgrids.

Transmission and distribution are increasingly coupled – as they used to be somewhat independent - both operationally and from a modeling perspective. Examining this change from an integrated grid planning perspective will be of increasing importance and not straightforward. Enhancement and additional development are needed for distribution planning and transmission planning tools. The balance between centralized and decentralized (disaggregated) generation requires a change in system operator decision-making processes.

The distribution system operator (DSO) has to balance the local load and, possibly, micro-grids. This could be of help to CAISO. Some participants argued that grid services, such as voltage support and frequency regulation, should be done on distribution networks and not on transmission systems. Pushing regulation down to the DSO needs to occur to make balancing easier when supply and demand are physically closer. This is now happening due to the rapid increase of behind-the-meter (BTM) generation and storage. This could allow for an avoidance of some distribution and transmission upgrades.

Having better control allows the system to more easily transform to address new realities. That is, demand management may be the key in the future. How do the Demand Curve and the Supply Curve compare? Currently, the approach is to make Supply match constantly changing Demand. In the future the approach will be to make Demand match constantly changing Supply. For a low-carbon grid, managing demand will become as important as

managing supply. This is because BTM activity is "invisible" to CAISO which sees only net load.

There are concerns are about EV charging. The timing and impact to the grid, including mechanisms for determining how consumer demand will grow and how this relates to single-family, multiple family, and commercial establishments as charging stations are installed. The pace of deployment could become a challenge. Additionally, the time when EV charging occurs will either decrease or increase carbon emissions with the current fleet of electricity generators – decreasing emissions during the afternoon and increasing them at night.

For BTM solar generation, there will be a need to adjust subsidies and to factor in the role that storage will play in the future. It will be easier for a DSO to evaluate the ramifications of these changes that are occurring simultaneous to increasing percentages of utility-scale renewables coming on line. California has been an international leader in energy efficiency codes, standards, and technology development. One interviewee believed that California has not been sufficiently aggressive in recent energy efficiency activities. The thought is that the state must continue to be aggressive as the less electricity we use, the lower the carbon emissions would be.

There will also be a need to incorporate new demand response (DR) technologies into the grid and with end users. This technology will allow for load shifting from times of high renewable energy output to times when electricity is needed. There remains a need to signal, incent, control, and monetize DR. Technologies, such as improved two-way communications and better monitoring and information technologies, need to be developed that will allow for automated DR. This will allow the system operator or DSO to better manage grid services and avoid frequency and voltage excursions, among other potential problems.

Impacts on consumers of different economic means need to be addressed. Well-to-do people who can afford to install BTM solar are subsidized by poorer people who pay higher rates for maintaining the grid infrastructure. Grid costs shift to those who lack capital, but must pay higher electricity prices to maintain grid operations. There will be a need for community support which incorporates equity, affordability, and data privacy. Public education is essential.

There is a need to educate workforce to install these new technologies. And, there is a need to consider overall gains and losses in jobs - not just net gain. That is, there will be a geographical disparity between areas where there are job gains and job losses.

Technology Development Considerations

Technologies need to be developed or improved considerably in order to meet the needs of a changing grid. There was considerable discussion concerning the need for energy storage on the grid for ensuring system reliability. An issue that has recently been raised about lithium-ion systems is the availability of other elements, such as cobalt and rare earths that must be imported. It is possible that these system prices may soon bottom out and start to increase as the raw materials increase in price.

Long term duration storage systems will be necessary for seasonal and weather-related problems, not just for addressing ramping and other grid stability issues. However, other than pumped hydro, these technologies are currently not commercially available. There will also be a need to improve communications and controls to properly dispatch all storage, including behind the meter storage. The US Department of Energy and the CEC are funding a number of development projects in this area.

One possible solution would be for economically competitive hydrogen production technology. This program would need to develop solutions for physical storage, transportation, and lower cost "green" hydrogen generation. Recently, California has passed legislation promoting "green hydrogen." That is, rather than produce hydrogen from methane, which produces carbon dioxide, hydrogen is produced from electrolyzing water.

Currently, the affordability of this process is not good, due to the inefficiencies associated with electrolysis. There is considerable research and development occurring in this area. In addition, Intermountain Power Project in Utah is converting some of its facilities to eventually focus on hydrogen production and storage as well as compressed air energy storage (CAES). While proponents are enthusiastic about this new demonstration, other interviewees thought it was too risky. Other opportunities for hydrogen production are to use excess solar, that would normally be curtailed, to produce hydrogen. There was considerable debate among the interviewees concerning costs of hydrogen production. Proponents believed that it could eventually cost $1.50/kg, while those that were not positive on hydrogen pointed out that overall production, distribution, and refueling infrastructure prices for hydrogen range to around $15.00/kg.

New and improved generation technologies include nuclear, in the form of small modular reactors (SMR), carbon capture and storage (CCS), bioenergy, and off-shore wind. SMR proponents point out that nuclear power production does not emit any GHGs. However, state law precludes any new nuclear power development in the state until a permanent national repository has been opened.

CCS received a number of positive comments by interviewees. Interviewees from industry believed that CCS could provide answers to their problems related to their need for industrial heating requirements. These industries could continue to use natural gas and capture the emissions. For the electricity grid, CCS would also allow for the use of thermal generation that would improve grid stability, while still allowing for the removal of carbon dioxide from emissions. This feature would be consistent with California's carbon neutrality goals.

Some of the interviewees also discussed opportunities and issues associated with biomass combustion and conversion. Currently, biomass is more costly than solar and wind. There are 29 facilities in California that could operate, although twelve are not running as they do not have customers due to the high cost of electricity from biomass combustors. Depending on the location, one interviewee indicated that the transportation limit to economic use of biomass is on the order of fifty miles. On the positive side, forest thinning could provide inexpensive biomass resources. Further, the "Placer County Study" on releases of PM2.5

and other criteria pollutants noted that biomass facilities produce 98% lower emissions than wildfires.

The final new technology that was discussed was offshore wind. In northern Europe and on the eastern seaboard of the United States, offshore wind is becoming increasingly important to meeting grid needs. The offshore advantage is the ability to construct many megawatts of generation at one site which will have capacity factors considerably greater than onshore wind. In California, two offshore locations may be viable for offshore wind. On the Central Coast, this region can absorb some new wind without transmission issues. Humboldt County is another area with good potential sites, but there is little electricity demand in that region.

There are limitations to the ability of offshore wind to come on line quickly. In other regions of the world with offshore wind, there are continental shelves. For example, there is considerable offshore wind in the Baltic and North Seas. However, the seabed in these locations is generally not much more than one hundred feet below the water surface. Thus, these facilities can be embedded in the seabed. There is essentially no continental shelf off of California's coast. Thus, new technology or technology from offshore oil and gas production would need to be used. This is at the moment uneconomical for offshore wind. Additional problems include environmental and esthetic issues, cultural (tribal) issues, and opposition from the fishing industry and the Navy.

Industry Comments and Observations

Traditional investor-owned utility's survivability is under extraordinary financial and political pressure. There is an urgent need to address challenging regulatory and political regimes (administrative friction, implementation, and interconnection delays). In the meantime, local communities are not eager for new transmission, utility-scale wind and solar, etc. Resistance to new infrastructure will delay development of new energy resources.

Calpine, as an independent power producer (IPP) in California analyzed how to decarbonize the state economy. Calpine currently has a fleet of primarily gas-fired generation. The company is considering the future of gas and how it fits in with decarbonization efforts. Calpine is more optimistic about CCS as compared to hydrogen. Calpine's analysis included electrifying other sectors and found a 60% increase in electricity demand by 2050 [4]. The study showed that meeting higher demand in a carbon neutral future requires lots of renewables, significant short duration batteries. However, there was also a need to maintain gas-fired generation where gas served a capacity and reliability role, but provided significantly less energy.

What is difficult to address with renewables + storage is days and/or weeks of low renewable generation. Restricting gas will lead to massive overbuild of solar and storage at significant cost. Allowing CCS, nuclear, and hydrogen also makes electricity cheaper. Retrofitting existing gas plants with CCS is the cheapest option. As a result, Calpine is pushing forward with CCS in California and Texas as CCS provides a good opportunity for decarbonizing industry. That is one reason Calpine focused on the Sacramento river delta, where there are large industrial sources, leading to an opportunity to leverage the same infrastructure for generation, refineries, and other industrial sources. There are two CCS

pilots underway - one with Ion Clean Energy (which has a new solvent for capture to reduce cost), and one with Blue Planet Ltd (using captured carbon to make building materials).

For Investor-Owned Utilities (IOUs), the use of demand response has proved helpful during periods of high demand due to heat waves. However, San Diego Gas & Electric (SDG&E) doesn't want to continually rely on it. SDG&E believes that proper planning is critical. Grid operators should be ahead of changes that will occur. Utilities need to react in a timely manner and make the correct power purchases over the next 10 years. Thermal generation retirements are happening rapidly, primarily baseload generation.

Community Choice Aggregators (CCAs) are now procuring electricity more responsibly. Initially, CCAs were primarily buying renewable energy credits (RECs). CCAs allow communities to pool their electricity load, purchase clean energy, and develop local projects and programs on behalf of residents and businesses. They have grown recently in order to achieve goals of reducing emissions at lower cost. There are now 24 CCAs in California, providing service for 25% of the population and about 33% of the electric load. CCAs will be important for the future clean grid, because customers want lower GHGs at lower cost. Having CCAs participate may be a challenge, as this can complicate the overall operation of California's grid.

Section IV: Transportation

"Need a RETHINK of how infrastructure for EV charging is created…e.g. charge at the powerplant, bring the battery to the vehicle"

Regarding EV trucking "the technology is not ready"

To be successful, California's carbon neutrality goals will need all the vehicles that comprise the transportation system (cars, trucks, trains, marine traffic, and airplanes) to stop using fossil fuels. The state will need to move away from petroleum products and natural gas to new power sources, such as fuel cells, biofuels, and electricity. The major issue is that, to produce more electricity for electric vehicles and to produce hydrogen (green hydrogen) for fuel cells or internal combustion engines (ICE), there will be a need to significantly expand the amount of electricity being produced.

Interviewees noted that there are issues with the long-term transition away from ICEs. Many ICE vehicles on the road today will be on the road in 2035 when there is supposed to be a moratorium on sales of new ICE vehicles fueled by gasoline or diesel. One "advantage" that California has is that cars last 15 to 17 years due to its relatively benign climate. One interviewee noted that 30% of new cars are purchased by 6% of population. Many other residents are purchasing used vehicles. It is uncertain as to how used EVs will be re-sold, given issues with battery cost and battery life.

It was noted by many interviewees that aviation is nowhere near converting away from jet fuel. Marine transport is evolving due to changing international requirements. However, in the shipping industry requirements are for changing from one fossil fuel to another - heavy bunker fuel to liquefied natural gas.

For rail transportation, California has a state plan. Expansion of passenger rail can shift single vehicle driving to rail. Three of the five busiest Amtrak routes in the country are in the Central Valley. Currently, freight rail is deemed excellent, but is all powered by diesel. There will be a need to electrify where possible. However, electrification is not effective on steeper grades. Electrifying rail transportation will produce challenges with siting substations and with expansion of catenary lines that many find visually unappealing. CalTrain is being electrified, but LA Metrolink and all current rail in Central Valley are still powered by diesel.

Governmental Leadership

Many of the interviewees pointed out that there is a need for governmental leadership that goes beyond just setting goals. Specifically, there needs to be an ability to fast track permitting operations for installing charging stations around the state. In doing so, this will provide for job creation. Local permitting can be a problem as it may take years to get permits for charging stations and permits for upgrading transformers. Permitting for interconnections currently poses problems in terms of arguments between utilities and behind-the-meter generators and storage providers and users. There is a long, unsatisfactory process for siting and locating public charging stations. One interviewee pointed out that a charging permitting effort took eighteen months with no resolution. The process is slow and expensive even with consultants. California regulations are extremely

prescriptive. As industry leaders noted, permitting delays and conflicting regulations increase costs without substantively reducing emissions.

Thus, leadership is needed, preferably with state agencies and utilities working together, to determine where to place chargers and a timetable for doing so. A piecemeal approach to charging infrastructure without proper planning is not the correct approach. A significant opportunity will be for utilities and the state to do a collaborative study on "Here is a map of where we should site new chargers." The utilities could do an evaluation of where these chargers could be sited and lower costs. This analysis should be made public. Otherwise, every customer is going to install chargers and then try to install on-site generation. With the proper collaborative leadership, there could be an agreement to plan for a "Big Network," by building incrementally according to an agreed upon plan. Currently, only a small fraction of 36 million California vehicles are zero-emission, less than one million.

Electric Vehicles – Positive Opinions

There was a widely divergent set of opinions in describing how easy and cost-effective broad conversion to EVs was going to be. A number of interviewees said that the emergence of new EV companies and the transition of existing automobile manufacturers to EVs illustrate that EVs are now seen as preferable to ICE vehicles on the basis of life-cycle costs. That is, while the initial cost of a vehicle may be more expensive, the reduced fuel and maintenance costs will be, overall, less costly for an EV. Some interviewees mentioned that they believed that gasoline prices would increase substantively in the future.

Some interviewees predicted that commercial vehicles – in terms of fleets – might be the first large-scale conversion to EVs. Commercial EVs will sell based on lower Total Costs of Ownership (TCO). Customers will tend to be fleet operators. Large-scale deployment will start occurring for transit, school, and para-buses starting in 2023. One interviewee believed that EV transit buses are economical now. Ford has an EV E450 chassis which can have an ambulance body attached to it. Another EV application is "last mile delivery" for e-commerce retailers where the daily route is less than 200 miles. Most EV applications are one-charge-per-day and usually outside daytime working hours. Another alternative would be battery swapping in the evening, although this may end up being more expensive.

As more vehicle producers provide new EVs for this market, these changes allow other types of equipment to enter the EV market. Construction and excavation equipment may be viable now, with smaller equipment (Bobcats), larger equipment (Komatsu), and large-scale mining equipment amenable to conversion to electricity. Battery costs for all of these applications are coming down, but charging capacity currently does NOT scale. For a fleet, building out lots of charge points may be costly enough to shift TCO back to fossil fueled vehicles.

Electric Vehicles – Negative Opinions

A number of the interviewees raised questions and doubts about how fast the charging infrastructure could be built out. One cited a study indicating California will have eight million EVs on the road by 2030 and wondered where will they charge. New technology, such as parking lot-based portable chargers (~$60k) may be available. Then a dedicated charging spot (static charger ~$20k) is not needed. A number of interviewees also

commented that charging time could pose a challenge, if it's noticeably longer than for liquid fuels.

There needs to be a concerted effort, as described above, to find a variety of locations for chargers. This would include new apartment buildings, retrofitting old apartment buildings, other multi-family homes, and offices. In many cases building codes need to be updated for new wiring requirements for charging. "EV-Ready" construction may not be straightforward. Details of conduits, space, protection, and the size of the future charger footprints may be more difficult for existing structures. Consideration also needs to be given for the many locations where people park on the street. Finally, attention needs to be given to providing charging for low-income housing. To assist low income families, new programs, akin to "cash for clunkers," could be started that will allow these families the ability to get newer EVs and not simply get another used car.

To close this sub-section, an additional number of comments are listed. Some interviewees were concerned about the price and ability to obtain the raw materials for battery production. Another concern is the ability to warranty the batteries and to properly re-cycle them. Additionally, the idea of vehicle-to-grid electricity is probably not warranted due to the limited number of cycles per battery, although shutting off chargers during peak demand periods (demand response) would be acceptable.

Trucking Perspective

Despite pronouncements from EV manufacturers, trucking industry executives were not sanguine about the conversion from diesel to electricity. Part of their overall concern is that there would be "leakage" at the state line. That is, their non-Californian competitors could still deliver goods into the state at more competitive prices. As a result, and because of new state regulations, some trucking firms are already setting up satellite facilities in other states. However, CARB states that trucks that mainly operate in California will still need to follow California policy and regulation, even if they are not registered in the state.

EV proponents believe that the economics that will favor EV adoption already pencil out for trucking firms due to fuel and maintenance savings. However, the trucking industry is concerned over start-up costs. Charging infrastructure does not scale as large numbers of trucks in a mobilization area will require megawatts of power. At this scale, charging point power demand will be huge. This will require transmission and distribution upgrades by the electric utility and must include lots of charging points in a concentrated area. For all of these infrastructure upgrades, it is unclear who will pay for them.

The trucking industry is also concerned that the technology is not ready for large-scale adoption of EVs for heavy duty vehicles. The capital cost for a new diesel is about $160,000, while the EVs on the market are about $640,000. Thus, even with a subsidy of $200,000 which is being considered, EVs will still be too expensive. Further, since trucks need to be operating all of the time to be profitable, charging as compared to refueling diesel may take too long a time.

Hydrogen

There was considerable discussion about hydrogen, either for fuel cells or for ICEs. A number of interviewees were quite positive about hydrogen, particularly "green hydrogen" that could be produced by solar energy during peak generation periods in the middle of the day.

There are a number of issues concerning hydrogen, such as storage, transportation, and infrastructure. Hydrogen could be combined with natural gas for better storage or confined in geologic formations. However, it is not known if a small molecule such as hydrogen could be safely and securely stored in these formations. Transportation of hydrogen is an issue. It may not be feasible to use existing gas pipelines. It may be necessary to blend hydrogen with natural gas to prevent leakage of hydrogen. There is also an issue of converting existing pipeline right of ways to hydrogen transport.

While acknowledging these issues of storing and transporting large quantities of hydrogen, there could be a step-wise process for such as a transition. Specifically, diesel could switch to CNG (which is already being used for a number of mass transit systems) and then converted to a CNG-H_2 blend, ultimately leading to hydrogen use in fuel cells. Bus fleets, universities, and the mining industry could be early adopters of hydrogen fuels.

One interviewee commented that hydrogen-fueled vehicles could have long distance and heavy payload applications that EVs do not have. However, major trucking and shipping companies are not in favor of hydrogen. Further, it is still not clear what the purity of hydrogen needs to be to effectively operate fuel cells. Both the automotive and trucking industries believe that the costs are still too high for transitioning to hydrogen fuel cells. For heavy duty trucks fuel cells are not cost-competitive. One interviewee noted that the capital cost for a fuel-cell powered heavy duty vehicle is about $900,000. Lastly, despite the push in an earlier California administration, there is no substantive fueling infrastructure available.

Section V: Buildings and Energy Efficiency

"Think of buildings as a grid resources that can contribute to grid reliability and resource adequacy"

"Need to transition thinking away from savings in 'energy' to savings in 'carbon' where TOU determines carbon consumption based on grid state"

"California has the most innovative and restrictive rules and codes"

"Need a palette of carbon-smart building materials"

Because of the use of electricity, from fossil-fuel power plants, and natural gas, buildings are responsible for significant carbon emissions. California regulations, such as Title 24, and new laws, particularly SB350, promote improved energy efficiency as a means to reduce energy use and carbon emissions. Amory Lovins has touted energy efficiency - "negawatts" - as the most cost-effective means for reducing carbon emissions from the buildings sector. Art Rosenfeld, who served as a California Energy Commission commissioner, is generally considered to be the "godfather" of energy efficiency. Since 1975, California has been a national leader in developing new standards for buildings and appliances that reduce energy use, while maintaining the state's economy.

Recent regulations promote the reduction of carbon emissions in buildings. Interviewees and workshop attendees discussed this point and what the housing industry is doing to meet the new Zero Net Carbon standard for new homes. It should be noted that this standard has been changed from the original Zero Net Energy requirement to Zero Net Carbon as a more cost-effective means of reducing GHG emissions. New building construction is appropriate as a cost-effective means for reducing future carbon emissions. One interviewee believed that there will be no need to build gas infrastructure in the future. Solar panels can be sized correctly and storage can be integrated into the new building. These new approaches are consistent with Title 24 for minimum efficiency standards for new construction. Title 24 also has a GHG metric as part of its standards.

One concern associated with new housing construction is embodied emissions associated with new construction materials. Embodied emissions may appear to be a small piece of overall emissions when building timescales are on the order of 100 years, but the next 10 to 20 years matter most for climate change. The cement and steel industries are responsible for 10% of global emissions. In section VII of this report, the industrial response to California's carbon neutrality goals is discussed, including carbon-smart materials, such as reducing cement percentages in concrete. An additional factor for embodied carbon emissions is urban sprawl. New approaches should be considered which can reduce carbon emissions associated with developing additional infrastructure as well as longer commutes using gasoline or diesel.

Regulations for new homes will not solve the efficiency and carbon emissions problems associated with existing structures. It is estimated that there are over 14 million existing homes in the state. In 2020 there were 110,000 permits for new homes (we acknowledge

that the number of actual new builds may be higher). Thus, retrofitting existing housing stock needs to be addressed aggressively. Many retrofits are needed, such as replacement of single-pane windows and improved insulation. Conversion from natural gas to electricity for heating and cooking must be implemented. Emissions from existing building stock are considerable, with some structures being much worse than others. One commenter noted that 2-4% of existing buildings create half the emissions from buildings, generally from a small subset of large buildings in a downtown core. However, it should be noted that San Francisco now requires all big buildings to purchase green power. This change was done through the city's municipal code and not through an energy code.

The refitting of existing residences using existing energy efficient housing technology is a means to cost effectively reduce carbon emissions. There needs to be a structured process or "playbook" to provide direction in upgrading building efficiency. Part of this process should identify lifecycle "building intervention points" where work can best be done. This would include improved insulation around HVAC piping and attics, installation of better window types, insulation around entryways, and use of behind the meter storage and generation. This is seen as a more effective and lower cost long-term approach to carbon neutrality as compared to the requirement for zero net carbon new construction.

Incentives should encourage various approaches, such as subsidies for rented homes to become energy efficient. One commenter suggested that there be a requirement for retrofitting upon sale or a time frame for retrofitting energy inefficient homes. There is precedent for this in replacing toilets to conserve water. An impediment is how much time this adds to the time for sale. A suggestion is to provide a window of time before and after the sale for energy efficiency retrofits. Depending on the nature of the building, this could be at the time of sale, time of lease, during seismic upgrades, or with major equipment replacement. For larger buildings, upgrades can be timed with capital improvement cycles.

Another aspect of permit modification would be to subsidize landlords for retrofitting where the financial benefit accrues to the renters in the form of reduced utility bill. An example used by an interviewee is that for old apartment buildings, window replacement can reduce energy costs for renters from $160/month to $80/month.

The state should develop policies that will be clear and provide easy mechanisms for implementation. As one interviewee characterized this point, there should be a "Moonshot" for the massive amount of retrofitting to be done. This will allow vendors and workforce to be prepared. These policies should provide financing at low rates. To keep embodied emissions down, as many materials as possible should be reused. Incentives should be focused on technologies that will have the greatest carbon reduction impact. For these retrofits, low income families should receive priority for any subsidies. It should also be noted that conversion to electricity should have local health benefits due to a reduction of residential natural gas emissions.

A number of interviewees commented on the need to update codes and standards for buildings. Various building ordinances must be easier to understand and must reflect the need to reduce carbon emissions. Additionally, the need to properly upgrade professions such as electricians was also mentioned as a necessity. With the push for electrification of

buildings and industry, there is probably a lack of trained electricians. Electrification will require modifications to home designs. Thus, even architects may need additional education.

Local permit developers and inspectors would benefit from additional education. This is true for new devices that are being installed, such as heat pumps. Proponents of heat pumps believed that we should be more aggressive in promoting heat pumps and work harder to stop using natural gas. One interviewee believed that all legacy, carbon-emitting equipment, such as natural gas-fired heating devices, should be banned. This is similar to the phase out of incandescent light bulbs for LEDs.

There were a number of comments concerning the development of more buildings in urban centers. The main benefit is less commuting, thus reducing vehicle emissions. However, CEQA and other permitting requirements can be impediments to building housing. As one commenter noted, if the state is not streamlining permitting processes, it is not serious about decarbonizing. As with any of these developments, there will be opposition (NIMBY) that can delay or limit them. It may be difficult to build in urban cores near public transportation hubs. The cost of these residences could become an equity issue in terms of a lack of sufficient affordable housing. One commenter noted that constructing taller buildings increases construction costs in urban centers.

District level solutions could provide an approach worth considering. For example, district level (for example, a city block) heating and cooling and development of district level hydrogen infrastructures would be a means to address carbon neutrality from an urban perspective. As with many of these ideas there would need to be incentives and subsidies to promote these new approaches.

A number of studies have shown that load shifting (as part of demand response incentives) reduces overall carbon emissions from electricity generation [5]. CPUC and CAISO have indicated interest in determining how to structure and monetize rates (time of use [TOU] pricing) to encourage this DR. Some examples of load shifting are HVAC adjustments (2-way thermostats) water heating and water pumping. Complicated controls are still emerging and most devices don't have communications built in. Concerning DR, consumers need information as to when to run appliances when there are "excess electrons." As one workshop commenter said, "Don't tell me to turn off my AC," while the timing of car charging and laundry are less important.

Given the increased need for more efficient appliances, time is needed to ramp up supply chains and the training of the installation workforce. Manufacturers are not producing some needed equipment quickly enough. For commercial buildings, some large sized equipment (e.g. rooftop heat pumps) may not be economic today. There will be a need to work with manufacturers to test new equipment and get these to the market as quickly as possible. The caution will be to ensure that in moving too fast, the costs of new equipment do not increase dramatically.

Additional comments about rooftop solar were made by a number of interviewees. It was noted that the rooftop solar industry retains strong political power and that legislation has

been enacted for protecting the industry (even with repeal of earlier net energy metering regulations. There have been a number of studies done that show overall residential electricity use actually increases with the installation of BTM solar. Since almost all of these buildings do not generate enough electricity to go completely off the grid, these structures still need electricity from the grid. One interviewee commented that rooftop solar is bad for the grid, leading to surges in net load at times when load is peaking on a normal basis (the ramping issue mentioned in the Electricity section). During peak production, BTM generation can cause the curtailment of other cheaper renewable resources, such as utility-scale solar and wind. One interviewee proposed some adjustments to permitting BTM solar which would include requiring efficiency retrofits throughout the structure, demand response systems, and storage, as well as mechanisms for enabling curtailment of BTM solar generation.

With the phasing out of natural gas, there could be a need to conduct pilot projects on heat pumps. In particular, there is a concern that leakage of refrigerants being used in these devices could increase GHG emissions. One commenter noted that mandating electrification may not work due to a variety of practical issues, such as supply chain problems.

Section VI: Industry

"We want to be part of the solution"

"Maddening that we can't do things that other jurisdictions can do"

"CCS needs to be in the toolkit for the industrial sector"

The California business community supports climate change and carbon neutrality goals. However, there is a need for a better understanding of how to meet these goals and their costs. For industry to be profitable in California, there must be cooperation between the government and selected industries. There needs to be a focus on marginal abatement costs. By doing so, California regulators working with industry could develop a better approach for providing incentives. It was implied that such a discussion would lead to more business leaders coming forward in support of carbon neutrality goals.

A substantial amount of business innovation happens in California. However, they receive little to no recognition for this innovation. There is just more pressure to reach mandated state goals. Innovation within the private sector is one important way to achieve goals. Not engaging the business community when making decisions that impact the entire economy can be detrimental to achieving state goals. There is a need to integrate state efforts with broader issues, not just climate change. Housing and good jobs, for example, are critical for the development of the state economy. The state needs to ensure it is taking a systems approach to integrate and incorporate these other policy areas.

Concerns were raised about "Leakage." That is, industry is leaving the state for other states with less onerous carbon emissions regulations. California needs to develop mechanisms to ensure global competitiveness of in-state companies, while developing the carbon neutrality plan. It was noted that compliance costs for those that stay may become too expensive. There is also a need to streamline permitting for new developments that try to meet the state's carbon neutrality goals. Permitting and incentive pathways should be separate. Other incentives should include tax benefits.

Large industrial customers in California are energy intensive. Electricity can represent 30-75% of total costs. They are trade-exposed, as they have out-of-state and foreign competitors with operations with higher carbon intensity. Competitive responses could lead to higher emissions. If companies move out of state, production and transport (back to California) can lead to higher overall emissions.

Small manufacturers do not have the means to create or implement new technology. Small industry is being burdened with the challenge of decarbonizing. In the meantime, family-owned businesses employ seven million people in the state. Because many of them are small businesses, they do not have the financial ability to meet all aspects of new regulations.

Costs of industrial electricity in California are two times higher than some other states in the region. These are driven by investments in energy transition, use of electric rates to fund social programs, wildfire hardening, and reliability investments in the face of lower grid-scale capacity. Looking forward, concerns about future energy use for industrial players include shifting costs from residential customers to larger, industrial customers in the push for affordability and social equity. It is difficult to shift all carbon neutrality transition costs to business. California industries may become less competitive from a cost standpoint as compared to industries that produce the same products in other locations in the country and around the world. As one industrial sector interviewee stated, "there is a history of developing policy goals that look good on paper, but have major issues in trying to achieve these goals".

Other regulations are sometimes counter-productive to achieving carbon neutrality goals. Other waste by-products could also be used for heat, but rules on incinerating these materials essentially prohibit their utilization.

Many industrial processes use natural gas and don't currently have an electric alternative. These industrial sectors include cement, glass manufacture, and steel. Interviewees and workshop presenters discussed possibilities for transition to electricity for a heat source. There should be more pilot projects developed with the Energy Commission's EPIC program that will allow the industry to support the state's carbon neutrality goal. An example of where this is working is Norway. Heidelberg Cement is building a zero emissions plant at Brevik, Norway. It is receiving $2 billion Euros from the Norwegian government. Heidelberg Cement also owns three cement plants in California. Thus, collaboration, along with state subsidies, will be helpful in keeping the cement industry in the state.

Cement production is an energy intensive process. In addition to fuel required for production, carbon dioxide is produced as an unavoidable by-product of clinker formation. 60% of emissions are by-products, while 40% of emissions are from fuel use. Since very high temperatures are needed, electricity is not currently an option. Biofuel could have potential, but it is not economic at present. Hydrogen could be a possible fuel, but more research is needed to determine its feasibility. The cement industry is working on the development of "cellular concrete" which will be lighter in weight and result in less carbon emissions. The industry is working with CalTrans for approval of these materials for state roadbeds. Once approved, this should result in more product being developed in California, resulting in less emissions. The industry is also pursuing an ASTM standard as an additional option.

As part of industrial advances, interviewees recommended that architects consider new designs. Architects currently specify "old" concrete and overdesign, with a tendency to stick with old practices. There is a need to be intentional in reducing the quantity of construction materials and improving quality by using new cellular concrete that is less carbon intensive. Since the cement industry will always produce carbon dioxide, the interviewees were supportive of future commercialization of CCS. A recent decarbonization study demonstrated that CCS might be possible for this industry, but must be proven at scale at a cement plant [6].

CCS needs to be in the toolkit to decarbonize a number of industrial sectors. For example, Chevron is investing in next generation carbon capture companies to help scale this important technology. Their BECCS project in Mendota, CA is a demonstration project with DOE. Chevron is also investing in new technologies to make hydrogen cheaper and is also exploring renewable natural gas to hydrogen pathways. Since geothermal is promising, Chevron is investing in next generation geothermal companies.

Approaches to utilizing CCS should be emphasized as a solution for decreasing the climate impact from the industrial sector. Attempting to get rid of resources without measuring the net zero potential will decrease the options when solving for the climate crisis. There are projects that can be permitted, but the business case must be sound. Rather than forcing companies to change, approaches where private sector companies are allowed to innovate towards solutions will reveal more cost beneficial approaches. In fact, one participant suggested an economy wide cap on carbon emissions that could be put in place with the marketplace deciding where to target investments. This would help keep a diverse energy mix and allow for energy security, while finding the most cost-effective solution for the state.

Lifecycle and cost analyses of every energy resource and technology option should be developed. This would provide a database to compare decisions moving forward. A number of commentators were in favor of lifecycle emissions analyses of all energy technologies and resources. Other commenters stated that since every analysis reviewed demonstrated cost-effectiveness, there is probably a need for an independent unbiased analysis.

Section VII: Natural Resources and Agriculture

Livestock Industry feels "under attack" since the 1990s UN report "Livestock's Long Shadow"

"Too many permits (from the Farm Credit Association, CalEPA, CPUC, CARB etc) necessary for the implementation of anaerobic digesters"

"Government is subsidizing large dairies to get bigger"

"Forests are the best carbon capture and storage we've got!"

There were pros and cons associated with carbon sequestration processes in terms of biomass and soil sequestration. (Per agriculture, it should be noted that a number of requests for interviews were made to many people in state government and trade associations to discuss carbon neutrality issues related to farming. No one responded to our requests.) California has some of the most stringent forest management regulations on the globe. There is a need for better public education of contemporary forest management techniques. There is an inter-relationship between wildfires, land use, and biomass production. Prevention of catastrophic fires will substantially reduce the state's overall carbon emissions. In 2020, four million acres burned. As an example, the Creek Fire "exploded" because 60% to 70% of the trees were dead due to bark beetles and dryness caused by climate change.

There can be co-benefits between forest management and the development of various forms of bio-power. Fire resilience activities (forest thinning) will generate considerable biomass. Brush and small trees could be used as biomass feedstock. Rather than burning this wood waste, if biomass were used for electricity generation, the reduction in carbon dioxide emissions would be over 90%. This could be especially beneficial if CCS technology can be incorporated into the project. Bioenergy with carbon capture and storage (BECCS) is now seen as an essential component for reaching carbon neutrality goals. Issues with using this feedstock are the carbon emission costs from transportation and the financial costs in getting this low-density energy material from forests to a biomass combustor. A lack of long-term fuel contracts and power purchase agreements for biomass facilities inhibits their development.

Larger trees could still be used for construction. In fact, the use of "mass timber" as a novel form of engineered material could replace more carbon intensive building materials such as concrete and steel.

Natural climate solutions can include forest and soil carbon capture and storage. These solutions may be a benefit that can provide additional financial support to remote communities and the forestry and agricultural sectors. In finding value propositions for communities, the state should consider incentives to small landowners for promoting carbon sequestration practices. An additional environmental benefit is that these incentives may prevent conversion of agricultural land to housing, which has a carbon cost.

While many commenters painted a positive picture on the potential use of forestry lands for biomass production and carbon sequestration, another interviewee believes that all of this is wrong, or "Magical Thinking." Cap-and-trade offsets are simply future forests that will burn, releasing much more carbon dioxide in the long term. The carbon offset program has a 4% risk of loss in 100 years and is clearly unrealistic due to wildfires and climate change. Thus, forests are a net source - not a sink. This interviewee believes that "magical thinking" on soil carbon beloved by political appointees and environmental NGOs should be avoided as the actual research on this form of sequestration is limited. "This farm saved the climate and saved a community" checks a lot of boxes for politicians.

Biofuels can be made using residues from agricultural lands (e.g. corn stover) and not just by growing energy crops on this land. There was the view from one interviewee that the state should be skeptical of biofuels development using agricultural lands. The trade-off is using land for energy crops, rather than for food production. Analyses have shown that there is greater economic value in food production that in energy production. This interviewee also claimed that the IPCC does not have an accounting system for biomass and biofuels[d].

Livestock production accounts for about 3-4% of all GHG emissions in the U.S., most significantly in the form of methane. In the 1970s, 140 million head of cattle were needed to meet beef demand. Now, just 90 million head are required. At the same time, those 90 million cattle are producing more meat [7]. There has been no analysis that we are aware of on any benefit to "GHG efficiency" by having fewer cattle About 25% of California's methane emissions come from anaerobic dairy manure management and storage and 20% come from enteric fermentation. 2016 state legislation SB 1383 set a target of reducing livestock and dairy methane emissions to 40% below 2013 levels by 2030, which translates to a reduction of 9 $MtCO_2e$ by 2030 [8]. One interviewee said that the livestock industry is projected to reach a 4.6 $MtCO_2e$ reduction by 2030 White Oak Pastures is an example of reducing more emissions than are produced at their farms, with a focus on soil carbon management and use of new feed to reduce methane emissions.

For this sector, a technology focus is on anaerobic manure digesters. For dairy cattle, wet manure produced in barns, works well for digesters. However, for beef cattle in feedlots, dry manure is not a good candidate for digesters. Feedlot manure goes to compost, which releases more carbon dioxide than anaerobic digestion. For beef cattle who are "home-on-the-range," there is no option to collect manure.

There are a number of research activities underway to reduce methane emissions from cattle due to changing their feed. One commercially available product is a new additive (3-NOP) which reduces methane emissions. However, this chemical increased nitrous oxide emissions, which are more powerful greenhouse gases than methane. Seaweed feedstocks can reduce methane emissions, but contain a carcinogen. A life cycle assessment would be needed to determine GHG emissions associated with growing and transporting the seaweed feedstock.

[d] It should be noted that a multi-sectoral analysis done by the IPCC in 2010 was relatively clear and quantitative on life-cycle emissions for these energy resources

Section VIII: Socioeconomic Aspects of Meeting Carbon Neutrality Goals

"Need to find value propositions for communities"

"Combine bold climate agenda with bold labor and workforce agenda"

There is a perception that "Green is a job killer"

"CARB previously overpromised GHG benefits to the EJ community"

Impacts related to achieving carbon neutrality goals will cut across many sectors of the California economy. Comments made by interviewees may not be specific to a given technology or sector, but more broadly impact the state's economy as well as the economic impact on its individual citizens. This section is divided into three subsections: consumer behavior; job loss and creation; and environmental justice concerns.

Consumer Behavior

Consumer behavior will significantly impact the state's ability to achieve its carbon neutrality goals. The state, in addition to promulgating new laws, regulations and incentives, will need to launch educational programs that encourage average consumers to accept changes in their future purchases. "Normal" average people are the key. Part of this is behavioral change. For example, people want to run their dishwashers after dinner. Many people want to drive their ICE car until it dies. If in California the only new vehicle available is a costly EV, they'll buy ICE car in another state or on the internet. An analysis of how a potential carbon tax affects future consumer behavior would be useful for designing or modifying future governmental programs.

Some citizens will argue that these initiatives curtail freedom. There must be state programs to persuade, induce, and influence consumer behavior and decision making. Some in opposition may argue – and change customer perception in their arguments – that the state doesn't want people to drive. There must be programs designed to refute these arguments.

Part of a marketing campaign will be to change perceptions that, for example, gas is better than electricity for cooking and heating, in terms of reliability and cost. For transportation, the state must be more aggressive in providing alternatives, communicate benefits, and subsidies where necessary. To encourage reduced use of ICE vehicles, such alternatives could be other mobility solutions, the banning of free ICE parking, and provision for inexpensive transit passes.

Jobs

As one interviewee stated, "Combine a bold climate agenda with a bold labor and workforce agenda." Job creation and transition will become an issue of increasing concern. The focus should balance an evaluation of jobs lost in the fossil fuel industry versus additional jobs created in the renewable energy industry. It will be important to have labor representation in

these conversations. One interviewee observed that labor has a history of being excluded from this decision-making process.

Equitable solutions require job retention or improvement of job quality. There must be a just transition for displaced workers. There should be training programs for displaced workers and, where possible, they should be allowed to keep health insurance. It may be necessary for the state to develop and deploy subsidy programs for displaced workers.

There should be an acknowledgement that many fossil energy jobs are good-paying union jobs. Even if there is more job creation in renewable energy, they may not of the same quality and pay as lost positions in the fossil fuel industry. Development of more utility-scale solar would allow for a continuation of these types of positions both for construction and operation, but these installations generally have decreased needs for operations and maintenance compared with similar fossil facilities and will require fewer jobs. Residential solar installation and home insulation "green" jobs are generally non-union, itinerant, and lower paying positions.

There should be acknowledgement that major actions, such as decommissioning natural gas-fired power plants and refineries, will cause significant job loss. Since many of these workers live from paycheck to paycheck, a transition will need to be managed with immediacy. Retraining is easier within a company and much more difficult if major operations for that company leave the state. Re-training programs will need to provide financial assistance to workers going back to school. These individuals would probably not have the opportunity to earn a significant income while in school. Vocational education has been neglected in California in favor of college education. There will be a need to examine the educational system to provide opportunities to workers in mid-career who have lost their jobs.

There will be an increased need for electricians as much of the economy. This will occur as transportation, industry, and buildings electrify. In contrast, there is a likely loss of jobs for pipefitters due to the decreased use of natural gas for cooking and heating. One interviewee believed that there could be future jobs for former refinery workers in areas of well-capping and clean-up. Additionally, development of CCS facilities could provide new job opportunities for former fossil power plant, refinery workers and other oil and gas personnel.

There can be significant impacts on communities. For communities that are almost completely dependent on one employer, when that company closes its facility the economic impact may be significant. California should consider the model developed by the US Department of Defense when they closed bases across the country when implementing the Base Realignment and Closure Program (BRAC). This effort required support to communities who were significantly impacted by base closures.

The state can assist in job creation analysis. There will be a need to develop case studies that will inform the government's approach for ensuring that carbon neutrality impacts on workers are minimized. Some of these case studies could include:

- Refinery conversion from oil refining to renewable bio-diesel
- Analysis of jobs now (gasoline, diesel) v. future (EVs)

- Gas power plants still operating, but maintained at low capacity factors only for grid stability and reliability – impacts on jobs.
- Job transition from unionized to non-unionized, and impact on workers
- Upkeep of building infrastructure providing employment – impact of increased electrification and reduction of natural gas use

One commenter observed that there are problems in funding to train people for clean energy jobs. Many get hired in other industrial sectors. For low-income worker programs in California, there is not much coordination with different agencies doing different things. It would be useful to better understand how these programs interact with each other and which ones should be emphasized.

State and federal agencies can promote good jobs by being linked to labor agencies for technical assistance. Training should be part of this, but should be connected to the development of jobs where the income is sufficient to support families. These can include job areas such as distributed energy systems (solar and storage), installation of energy efficient building technologies, transportation (ride-sourcing), waste management and recycling, forest fire prevention and management, and advanced agricultural practices.

Public-private partnerships between the state and private sector employers will be necessary. This will require customizing partnerships with different industrial sectors. Some elements for future efforts include the government having terms and conditions for any money invested in work force development in the path to carbon neutrality (e.g., wage standards, targeted hiring methodologies, more in-sourcing, etc.). This focus will be crucial to ensure we accomplish our environmental and social justice objectives. Apprenticeships should be supported and enhanced. New niche "green" jobs training programs should not be created in cases where these positions would not be long lasting. Comprehensive training should be funded that prepares workers for careers, not one technology. In terms of inclusion, it can't be improved without job quality. An example of this is in the trucking industry, where a misclassification in the trucking industry meant that low wage truck drivers were responsible for meeting the requirements of state policies and regulations, rather than the trucking companies they work for. Emissions reductions weren't fully realized because these truck drivers can't afford to comply.

For boilermakers, there are a number of low wage trouble spots where improved standards can improve job quality. Despite the fact that the current boilermaker business relies on the fossil fuel combustion industry, they do not deny that a transition is needed. They plan to transition to other jobs. "Stay out of our way. Let us transition." Boilermakers do not want money from the government. No one has defined what "just transition" actually means. Is it money for retirement or giving us welfare? We are not putting our workers on welfare. "Leave us alone, we will take care of ourselves."

Two thirds of people in CA don't have a 4-year college degree. One presenter said that these degrees are not needed to be successful. Apprenticeships can lead to successful careers. There is a need to incentivize K-12 schools (as in Illinois) to have technical/career focused education, including machine shops, carpentry, electrician classes, auto repair, etc. Career focused classes should count toward getting into the UC and Cal State systems. There is a

need for educated people to repair and maintain ZEVs. Community colleges in CA have apprenticeship programs for Associate Arts degrees that could be linked to high schools. There is an opportunity to provide foundational knowledge that will be useful over a lifetime career. We should start with the jobs that are needed, and then build the training program from there.

Environmental Justice (EJ) Concerns

Many of the interviewees raised environmental justice issues as a major concern. There was consensus across many interviews that the state must be made more aware of these concerns and try to do something about them. As one interviewee put it, many of the laws and regulations are developed by people who may have good intentions, but do not understand the needs of low-income families and the diverse population of the state. In fact, some in the EJ community find some things "deeply offensive" that scientific community finds reasonable. There has not been an independent assessment of the impact of specific policies on low-income families and their environment.

There may be perceived obstacles between carbon neutrality goals and goals of environmental justice. One possible solution would be to put innovative clean energy efficient technologies in low-income areas first so that they would be the first to benefit. The state needs to make sure everyone has access to affordable heating/cooling and transportation. This may entail massive government subsidies. By taking this approach, technology costs will come down with growth and economies of scale. One commenter mentioned that the state needs to be careful about price points coming down due to exploitation of labor, for example, by importing products from China.

Other sustainability aspects, such as air pollution impacts, distribution of economic burdens, and access to green technologies and jobs need to be considered. We can't look at decarbonization alone. Electrifying transportation will lead to co-benefits from reduced damages from air pollution that are usually borne by lower income communities. However, if there is a premium on low carbon vehicles, adoption must be incentivized for low income families to ensure they are not overburdened. Current subsidies typically benefit wealthier people.

The EJ community is concerned about pollution from fossil fuels and perceives that fossil fuels cause inequitable health risks. This includes concerns about communities near ports and major land transportation centers. The problem with some of these concerns is that they are conflicted by the fact that facilities that are being asked to shut down also provide jobs to low-income communities. These locations include refineries and natural gas-fired power plants. As described in a previous section, many interviewees believe that natural gas plants should continue to provide electricity to the grid for reliability purposes. However, the EJ community does not want these located near lower-income neighborhoods. As one interviewee asked, "How many gas peaker plants are going to be sited in Marin County?" A partial answer to this issue would be to encourage and fund the training of people of diversity to obtain jobs in the renewable energy industry.

During the workshop, there were genuine concerns about air quality issues that impede public support for projects that need to be completed to reach carbon neutrality goals. The

state needs to think of more holistic strategies for air quality management. There is a concern that, if the state doesn't find solutions to this issue, it won't be able to reach its carbon neutrality goals. One commenter pointed out that there is "hysteria" about burning anything, which would limit waste-to-energy and biomass conversion technologies. An answer may be to conduct life cycle analysis assessments that would directly relate to air quality.

California needs to have programs that can provide subsidies for low income families for electricity and transportation. For electricity, prices are already high and will probably go higher to cover the cost of additional infrastructure development and deployment. In addition, more well-to-do home owners are installing BTM solar plus storage. The net effect is to reduce the overall customer base. As a result, fixed infrastructure costs are borne by people who do not have the means to pay for them. In other words, customers still on the grid will need to pay more for their electricity.

There is an EJ issue for the conversion of residential buildings from natural gas to electricity. As more affluent home-owners transition to electricity, fewer customers are on natural gas networks. The burden of maintaining this network will fall upon customers less able to afford these increased costs. Thus, for both electricity upgrades (including improving the overall efficiency of old houses through better wiring and insulation) and natural gas transition, there will be need to be subsidy programs to help low-income families.

There are EJ concerns in the personal transportation sector. Low income people generally have older cars. When they buy a newer vehicle, it will tend to be a newer used car. There will be a need for subsidies to make EVs more affordable for disadvantaged communities. This will require a program for getting charge points into low-income areas. There will eventually be a need for a market for used ZEVs that low-income population can afford.

There is a need to bring the EJ community into early discussions in order to obtain their concerns and insights. A number of interviewees noted that the EJ community is a self-represented movement of marginalized people. These communities are generally people of color. The EJ movement works at the grass roots level, with no one in charge. There is a need to recognize that the historic marginalization of these groups has "poisoned the well." Even an honest analysis can come off as unbalanced to the EJ community. As one interviewee said, a positive outcome for the Stanford effort would be to develop a bridge between the EJ community and advocates for market-based mechanisms and solutions.

Closing Observations

Some of the commentary presented in this report is not the view of members of the Stanford project team. The intent of these interviews was to obtain opinions and observations from a variety of people across a variety of sectors and stakeholder groups. The follow-on workshop was informed and shaped by this commentary. A secondary objective was to try and get as many organizations and people "under the carbon neutrality tent" as possible. It was not the intent of the interviews to simply re-affirm conclusions and programs developed by government policy makers and regulators, but rather to broaden the conversation.

To accomplish the state's carbon neutrality goals, the state must consider concerns and opinions from across a considerable spectrum of interests to best make progress in reaching our goals. California is a leader in the fight to combat global climate change. Global climate change is often perceived as a potential existential threat. It is no longer potential due to the reality of wildfires, drought and sea level rise. It is already here.

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